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COMPLETE ANALYSIS ON THE NLO SUSY-QCD CORRECTIONS TO $B^0 - \overline{B}^0$ MIXING

Tai-Fu Feng[a,b,d] Xue-Qian Li[a,b,d] Wen-Gan Ma[a,c,d] and Feng Zhang[b]

[a]CCAST (World Laboratory), P.O.Box 8730, Beijing 100080, China
[b]Department of Physics, Nankai University, Tianjin 300070, China[1]
[c]Department of Modern Physics, University of Science and Technology of China, Hefei 230026, China
[d]Institute of Theoretical Physics, Academia Sinica, P.O. Box 2735, Beijing 100080, China

Abstract
We present a complete next-to-leading-order calculation of the QCD corrections to $B^0 - \overline{B}^0$ ($K^0 - \overline{K}^0$) mixing in the framework of the minimal flavor violating (MFV) supersymmetry. We take into account the contributions from the gluino and find that the gluino-mediated corrections modify the LO result obviously even when the mass of gluino $m_{\tilde{g}} \gg m_{\rm w}$. In general, one cannot neglect gluino contributions.

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1 Introduction

As the most popular candidate for new physics beyond the standard model (SM), the supersymmetry[1] has been studied extensively during the last two decades. Even so, there is no experimental evidence for any of the new particles predicted by various supersymmetry (SUSY) models at present. Before new colliders are available searching for new physics, we should focus on indirect probes of the phenomena induced by SUSY at low energies. At this point, the most promising processes that we can depend on are the Flavor Changing

[1]The post address

Neutral Current (FCNC) processes, especially $b \to s\gamma$ and oscillations of neutral mesons. For weak decays at presence of the strong interaction, evaluating such processes requires special technique. The main tool to calculate concerned quantities of those processes is the effective Hamiltonian theory. It is a two step program, starting with an operator product expansion (OPE)[2, 3] and performing a renormalization group equation (RGE)[4] analysis afterwards. The necessary machinery has been developed over years[5, 6, 7, 8, 9]. The new physics effects on the rare B processes are discussed in literature. The calculation of the rate of inclusive decay $B \to X_s\gamma$ is presented by authors of [10, 11, 12] in the two-Higgs doublet model (THDM). The supersymmetric effect on $B \to X_s\gamma$ is discussed in [13, 14, 15] and the NLO QCD corrections are given in [16]. The transition $b \to s\gamma\gamma$ in the supersymmetric extension of standard model is computed in [17]. The hadronic B decays[18] and CP-violation in those processes[19] have been discussed also. The authors of [20] have discussed possibility of observing supersymmetric effects in the rare decays $B \to X_s\gamma$ and $B \to X_s e^+e^-$ in the B-factory. Studies on decays $B \to (K, K^*)l^+l^-$ in SM and supersymmetric model have been carried out in [21]. The SUSY effects on these processes are very interesting and studies on them may shed some light on the general characteristics of the SUSY model. A relevant review can be found in [22]. For oscillations of $B_0 - \overline{B}_0$ ($K_0 - \overline{K}_0$), calculations have been done in the Standard Model (SM) and THDM. As for the supersymmetric extension of SM, the calculation involving the gluino contributions should be re-studied carefully for gluino has non-zero mass. In this paper, we will present a complete analysis of SUSY-QCD corrections to the oscillations of $B_0 - \overline{B}_0$ ($K_0 - \overline{K}_0$) in the supersymmetric extension of SM with the minimal flavor violation, i.e. the flavor violation occurs only via the charged current at the tree level.

Our main results can be summarized as follows:

- We give a complete computation of supersymmetric QCD-corrections to $B_0 - \overline{B}_0$ oscillations up to NLO, our technique can be applied to compute SUSY-QCD corrections to other rare B-decay processes (such as $b \to s\gamma$ etc.) up to NLO.

- Additionally, we find that the gluino contribution to the NLO-QCD corrections grows as $\ln x_{\tilde{g}\mathrm{w}}$ when gluino is heavier than the lightest up-type scalar quark, where $x_{\tilde{g}\mathrm{w}} = \frac{m_{\tilde{g}}^2}{m_{\mathrm{w}}^2}$.

At the next-to-leading order approximation, the QCD corrections to the $B^0 - \overline{B}^0$ mixing in the SUSY model have been discussed recently. The authors of [23, 24] applied the mass-insertion method to estimate QCD correction effects on the $B^0 - \overline{B}^0$ mixing. However, in their work, the contribution from gluino ($\tilde{g}$) was ignored. It was thought that at high energies, $\alpha_s/4\pi \ll 1$, so that the correction induced by $\tilde{g}$ might be

discarded. The authors of [25] noticed the significance of the gluino contributions, however they only gave a general discussion without carrying out any concrete calculation on the gluino contributions. The calculation including the gluino-mediated QCD corrections needs new technique for $m_{\tilde{g}} > m_t$. In this work, our method is analogous to that employed in [25], but we develop the technique and handle all problems carefully, then draw our conclusion about the size of the gluino contributions through a reliable calculation.

The paper is organized as follows. In section 2, we display the necessary parts of the MSSM-Feynman rules and give the effective Hamiltonian without QCD-corrections. In section 3, we discuss the features of the NLO calculation with special focus on the explicit QCD- corrections and matching-procedure. Furthermore, we show that reasonably removing the contributions from SUSY-particles and the physical charged Higgs $H^{\pm}$, our result turns back to the SM result[26]. In section 4 we give the numerical results of the NLO and scan the extent of the parameter space in the MSSM with minimal flavor violation. We close this paper with conclusions and discussions. Some technical details are collected in the long appendices.

2 Notation and the box-diagram results

2.1 Notation and the Feynman-Rules

Throughout this paper we adopt the notation of [27], the expressions of the concerned propagators and vertices can be found in the Appendix of [27]. For convenience, we give the superpotential and relevant mixing matrices. The most general form of the superpotential which does not violate gauge invariance and the conservation laws in SM is

$$\mathcal{W} = \mu\epsilon_{ij}\hat{H}_i^1\hat{H}_j^2 + \epsilon_{ij}h_l^{IJ}\hat{H}_i^1\hat{L}_j^I\hat{R}^J + \epsilon_{ij}h_d^{IJ}\hat{H}_i^1\hat{Q}_j^I\hat{D}^J + \epsilon_{ij}h_u^{IJ}\hat{H}_i^2\hat{Q}_j^I\hat{U}^J. \tag{1}$$

Here $\hat{H}^1$, $\hat{H}^2$ are Higgs superfields; $\hat{Q}^I$ and $\hat{L}^I$ are quark and lepton superfields in doublets of the weak SU(2) group, where I=1, 2, 3 are the indices of generations; the rest superfields: $\hat{U}^I$ and $\hat{D}^I$ being quark superfields of u- and d-types, and $\hat{R}^I$ charged leptons are in singlets of the weak SU(2). The indices i, j are contracted in a general way for the SU(2) group, and h_l, $h_{u,d}$ are the Yukawa couplings. Taking into account of the soft breaking terms, we can study the phenomenology within the minimal supersymmetric extension of the standard model (MSSM). One difference between the MSSM and SM is the Higgs sector. There are four charged scalars, two of them are physical massive Higgs bosons and other are massless Goldstones. The mixing matrix can be written as:

$$\mathcal{Z}_H = \begin{pmatrix} \sin\beta & -\cos\beta \\ \cos\beta & \sin\beta \end{pmatrix} \tag{2}$$

with $\tan\beta = \frac{v_2}{v_1}$ and v_1, v_2 are the vacuum-expectation values of the two Higgs scalars. Another matrix that we will use is the chargino mixing matrix. The SUSY partners of charged Higgs and $W^\pm$ combine to give four Dirac fermions: $\kappa_1^\pm$, $\kappa_2^\pm$. The two mixing matrices $\mathcal{Z}^\pm$ appearing in the Lagrangian are defined as

$$(\mathcal{Z}^-)^T \mathcal{M}_c \mathcal{Z}^+ = diag(m_{\kappa_1}, m_{\kappa_2}), \tag{3}$$

where $\mathcal{M}_c$ is the mass matrix of charginos. In a similar way, $Z_{U,D}$ diagonalize the mass matrices of the up- and down-type squarks respectively:

$$\mathcal{Z}^\dagger_{U,D} \mathcal{M}^2_{\tilde{q}} \mathcal{Z}_{U,D} = diag(m^2_{\tilde{U},\tilde{D}}). \tag{4}$$

We present the relevant vertices in Fig.1 and Fig.2. a, b, c are the indices of SU(3) group in appropriate representations. We have explicitly written down the Yukawa-type couplings for the up-type quarks. For the down-type quarks, we use the symbol $h_{d^I} = \frac{m_{d^I}}{\cos\beta m_{\rm w}}$ to represent the Yukawa couplings and the short-hand notation $\omega_\pm = \frac{1\pm\gamma_5}{2}$ for the left- and right-handed projectors.

2.2 Box-diagram results

At absence of QCD corrections, the effective Hamiltonian for the $B^0 - \overline{B}^0$ mixing is obtained by evaluating the box diagrams (Fig.3). Neglecting external momenta and masses, the effective Hamiltonian for $\Delta B = 2$ transitions at the weak-scale is[28]

$$H^0_{eff} = \frac{G_F^2}{4\pi^2} m_{\rm w}^2 \sum_{ij} \sum_{\alpha} \lambda_i \lambda_j S_\alpha \mathcal{O}_\alpha \tag{5}$$

where $\lambda_i = V_{ib} V^*_{id}$ (V_{ij} are the elements of the CKM matrix with $i,\ j = 1,\ 2,\ 3$) and the operators $\mathcal{O}_\alpha$ are defined as

$$\mathcal{O}_1 = \overline{d}\gamma_\mu \omega_- b \overline{d}\gamma^\mu \omega_- b,$$

$$\mathcal{O}_2 = \overline{d}\gamma_\mu \omega_- b \overline{d}\gamma^\mu \omega_+ b,$$

$$\mathcal{O}_3 = \overline{d}\omega_- b \overline{d}\omega_+ b,$$

$$\mathcal{O}_4 = \overline{d}\omega_- b \overline{d}\omega_- b,$$

$$\mathcal{O}_5 = \overline{d}\sigma_{\mu\nu} \omega_- b \overline{d}\sigma^{\mu\nu} \omega_- b,$$

$$\mathcal{O}_6 = \overline{d}\gamma_\mu \omega_+ b \overline{d}\gamma^\mu \omega_+ b,$$

$$\mathcal{O}_7 = \overline{d}\omega_+ b\overline{d}\omega_+ b,$$

$$\mathcal{O}_8 = \overline{d}\sigma_{\mu\nu}\omega_+ b\overline{d}\sigma^{\mu\nu}\omega_+ b, \tag{6}$$

with the parameter $x_{i\mathrm{w}} = \frac{m_i^2}{m_{\mathrm{w}}^2}$, the coefficients S_α are given as

$$S_1 = \Big(\Big(f_a(x_{i\mathrm{w}}, x_{j\mathrm{w}}, 1, 1) - 2\frac{\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2k*}}{\sin^2\beta} x_{i\mathrm{w}} x_{j\mathrm{w}} f_b(x_{i\mathrm{w}}, x_{j\mathrm{w}}, 1, x_{H_k^-\mathrm{w}})$$
$$+\frac{x_{i\mathrm{w}} x_{j\mathrm{w}}}{4\sin^4\beta}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2k*}\mathcal{Z}_H^{2l}\mathcal{Z}_H^{2l*} f_a(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{H_l^-\mathrm{w}})\Big)$$
$$-\frac{1}{4}a_{+,i}^{km} b_{-,j}^{kn} a_{+,j}^{ln} b_{-,i}^{lm} f_a(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}})\Big),$$

$$S_2 = \frac{1}{4}\Big(\frac{h_d h_d}{2\sin^2\beta}\Big(\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k*}\mathcal{Z}_H^{2l}\mathcal{Z}_H^{1l*} x_{j\mathrm{w}} + \mathcal{Z}_H^{2k}\mathcal{Z}_H^{1k*}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l*} x_{i\mathrm{w}}\Big) f_a(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{H_l^-\mathrm{w}})$$
$$+\Big(a_{+,i}^{km} b_{+,j}^{kn} a_{-,j}^{ln} b_{-,i}^{lm} + a_{-,i}^{km} b_{-,j}^{kn} a_{+,j}^{ln} b_{+,i}^{lm}\Big)\sqrt{x_{\kappa_k\mathrm{w}} x_{\kappa_l\mathrm{w}}} f_b(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}})\Big)$$
$$-\frac{1}{4}\Big(-2h_d h_b \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1k*} f_a(x_{i\mathrm{w}}, x_{j\mathrm{w}}, 1, x_{H_k^-\mathrm{w}})$$
$$+\frac{x_{i\mathrm{w}} x_{j\mathrm{w}}}{\sin^2\beta} h_d h_b\Big(\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2k*}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{1l*} + \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1k*}\mathcal{Z}_H^{2l}\mathcal{Z}_H^{2l*}\Big) f_b(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{H_l^-\mathrm{w}})$$
$$+\frac{1}{2}\Big(a_{+,i}^{km} b_{-,j}^{kn} a_{-,j}^{ln} b_{+,i}^{lm} + a_{-,i}^{km} b_{+,j}^{kn} a_{+,j}^{ln} b_{-,i}^{lm}\Big) f_a(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}})\Big),$$

$$S_3 = -2S_2,$$

$$S_4 = \frac{1}{4}\Big(\frac{x_{i\mathrm{w}} x_{j\mathrm{w}}}{\sin^2\beta} h_d^2 \mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k*}\mathcal{Z}_H^{2l*}\mathcal{Z}_H^{1l} f_b(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{H_l^-\mathrm{w}})$$
$$+\frac{1}{2}a_{-,i}^{km} b_{-,j}^{kn} a_{-,j}^{ln} b_{-,i}^{lm} f_b(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}})\Big)$$
$$-\frac{3}{8}a_{-,i}^{km} b_{-,j}^{kn} a_{-,j}^{ln} b_{-,i}^{lm} f_b(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}}),$$

$$S_5 = \frac{1}{4}S_4,$$

$$S_6 = \Big(\frac{1}{4}h_d^2 h_b^2 \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1k*}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{1l*} f_a(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{H_l^-\mathrm{w}})$$
$$-\frac{1}{4}a_{-,i}^{km} b_{+,j}^{kn} a_{-,j}^{ln} b_{+,i}^{lm} f_a(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}})\Big),$$

$$S_7 = \frac{1}{4}\Big(\frac{x_{i\mathrm{w}} x_{j\mathrm{w}}}{\sin^2\beta} h_b^2 \mathcal{Z}_H^{2k}\mathcal{Z}_H^{1k*}\mathcal{Z}_H^{1l*}\mathcal{Z}_H^{2l} f_b(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{H_l^-\mathrm{w}})$$
$$+\frac{1}{2}a_{+,i}^{km} b_{+,j}^{kn} a_{+,j}^{ln} b_{+,i}^{lm} f_b(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}})\Big)$$
$$-\frac{3}{8}a_{+,i}^{km} b_{+,j}^{kn} a_{+,j}^{ln} b_{+,i}^{lm} f_b(x_{\tilde{U^i}_m\mathrm{w}}, x_{\tilde{U^j}_n\mathrm{w}}, x_{\kappa_k^-\mathrm{w}}, x_{\kappa_l^-\mathrm{w}}),$$

$$S_8 = \frac{1}{4} S_7. \tag{7}$$

The functions $f_{a,b}(x_1, x_2, x_3, x_4)$ are given in the appendix.A and the new symbols $a_\pm$, $b_\pm$ are defined as

$$\begin{aligned}
a^{j,k}_{+,i} &= -\mathcal{Z}^{1j}_{\tilde{U}^i} \mathcal{Z}^{+*}_{1k} + \frac{x_{i\mathrm{w}}}{\sqrt{2}\sin\beta} \mathcal{Z}^{2j}_{\tilde{U}^i} \mathcal{Z}^{+*}_{2k}, \\
a^{j,k}_{-,i} &= h_d \mathcal{Z}^{1j}_{\tilde{U}^i} \mathcal{Z}^{-}_{2k}, \\
b^{j,k}_{+,i} &= h_b \mathcal{Z}^{1j}_{\tilde{U}^i} \mathcal{Z}^{-*}_{2k}, \\
b^{j,k}_{-,i} &= -\mathcal{Z}^{1j*}_{\tilde{U}^i} \mathcal{Z}^{+}_{1k} + \frac{x_{i\mathrm{w}}}{\sqrt{2}\sin\beta} \mathcal{Z}^{2j*}_{\tilde{U}^i} \mathcal{Z}^{+}_{2k}.
\end{aligned} \tag{8}$$

On purpose, we keep the Yukawa-couplings of the down-type quarks explicitly in Eq.5, so that we can discuss any possible value of $\tan\beta$ in the Higgs sector. This is different from some early works[29, 25]. Another point which should be emphasized is that Eq.5 can recover the one-loop result of [25] as long as considering the unitarity of the CKM matrix and discarding the Yukawa couplings of down-type quarks.

3 Explicit QCD corrections to the box diagram

3.1 The general method to compute the two-loop integral

In this section, we will give the explicit perturbative QCD correction up to $\mathcal{O}(\alpha_s)$. The Feynman diagrams are drawn in Fig.4, Fig.5 and Fig.6. Similar to the previous treatments[26, 29, 30], we will carry out the calculation in an arbitrary covariant ξ-gauge for the gluon propagator, where $\xi = 0$ represents the Feynman-'t Hooft gauge and $\xi = 1$ the Landau gauge. The W-propagators is set in the Feynman-'t Hooft gauge.

The two-loop Feynman diagrams including all SUSY particles can be categorized into five distinct topological classes (a),(b),(c),(d) and (e) in Fig.7. Fig.7(c) and Fig.7(d) are the self energy- and vertex-insertion diagrams respectively, whereas the other three classes are of complicated topological structures.

Fig.4(a, c, g), Fig.5(a, c, g) and Fig.6 (a, b, c, d) belong to the topological class shown in Fig.7(a); Fig.4(b) and Fig.5(b) belong to the topological class in Fig.7(b); Fig.4(f) and Fig.5(f) belong to the topological class in Fig.7(e); Fig.4(d), Fig.5(d) and Fig.6(e, f) belong to the topological class in Fig.7(c); Fig.4(e), Fig.5(e) and Fig.6(g, h, i, j) belong to the topological class in Fig.7(d). The double penguin diagrams Fig.4(h) and Fig.5(h) do not contribute for vanishing external momenta.

To obtain the physical quantities, we have to deal with ultraviolet divergence. The divergence stems from diagrams Fig.4(d, e), Fig.5(d, e) and Fig.6(e, f, g, h, i, j). In this case we employ dimensional regularization [31, 33] and we carry out the renormalization in the $\overline{\mathrm{MS}}$-scheme[31, 32].

For an effective Hamiltonian, all internal particles must be integrated out, namely, a condition that there exists at least one internal particle with $m_{int} \gg m_{ext}$ where m_{int} and m_{ext} refer to the masses of the internal and all external particles (bosons or fermions) respectively, is implied. In the case for $B^0 - \overline{B}^0$ or $K^0 - \overline{K}^0$ mixing, m_b and m_d should be set as zero in the resultant effective theory. At the 0-th order, e.g. when calculating the box diagrams, there is no problem in the limit of $m_b \sim m_d = 0$. However, when the QCD corrections are taken into account, $b-$ and $d-$quark lines become internal in diagrams Fig.4(a, b, c) and Fig.5(a, b, c), then under the limit $m_b \sim m_d = 0$ an infrared divergence emerges. The divergence is artificial and can be eliminated in the full theory. The natural way to handle this problem is keeping all internal-line masses to be non-zero at denominator of the propagators.

As well known, we need to achieve the effective Hamiltonian at lower energies and the QCD-corrected box diagrams would determine the boundary condition of RGE for the running of the Wilson coefficients. Therefore, the infrared divergence must be properly eliminated. In next section, following the standard procedures given in literature to build a matching between the full theory and the effective one at the scale$-\mu$, we can get rid of the troublesome infrared divergence.

In the THDM sector of MSSM, the calculation is standard and consistent with the previous work, but because of the large masses of gluino and squarks, we need to take a more general treatment for calculating the contribution of the two-loop diagrams which include gluino. In the following part, we will illustrate how to compute the loop integral and separate ultraviolet divergence in one example. In (d) of Fig.7, We have an integral as:

$$I^a_{(d),2} = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{(2\pi)^D}\frac{k^4}{(k^2-m_1^2)(k^2-m_2^2)(k^2-m_3^2)(k^2-m_4^2)((k+q)^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2)} \tag{9}$$

where the m_i $i = 1, \cdots, 7$ are the internal line (bosons or fermions) masses. The above integral can be decomposed as

$$I^a_{(d),2} = I^{a,1}_{(d),2} + (m_3^2 + m_4^2) I^a_{(d),1} - m_3^2 m_4^2 I_{(d),0}, \tag{10}$$

with

$$I^{a,1}_{(d),2} = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{(2\pi)^D}\frac{1}{(k^2-m_1^2)(k^2-m_2^2)(((k+q)^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2)},$$

$$I^a_{(d),1} = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{(2\pi)^D}\frac{k^2}{(k^2-m_1^2)(k^2-m_2^2)(k^2-m_3^2)(k^2-m_4^2)((k+q)^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2)},$$

$$I_{(d),0} = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{(2\pi)^D}\frac{1}{(k^2-m_1^2)(k^2-m_2^2)(k^2-m_3^2)(k^2-m_4^2)((k+q)^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2)}.$$

$$(11)$$

Now, we calculate the loop integral $I_{D,2}^{a,1}$ step by step. After the Wick rotation, it is written as:

$$\begin{aligned}
I_{(d),2}^{a,1} &= \int \frac{d^D k}{(2\pi)^D}\frac{d^D q}{(2\pi)^D}\frac{1}{(k^2+m_1^2)(k^2+m_2^2)(((k+q)^2+m_5^2)(q^2+m_6^2)(q^2+m_7^2)} \\
&= \frac{1}{(m_1^2-m_2^2)(m_6^2-m_7^2)}\int \frac{d^D k}{(2\pi)^D}\left(\frac{m_1^2}{k^2(k^2+m_1^2)}-\frac{m_2^2}{k^2(k^2+m_2^2)}\right) \\
&\quad \frac{1}{(k+q)^2+m_5^2}\left(\frac{1}{q^2+m_6^2}-\frac{1}{q^2+m_7^2}\right) \\
&= \frac{1}{(m_1^2-m_2^2)(m_6^2-m_7^2)}\frac{B(\frac{D}{2},\varepsilon)B(2\varepsilon,1-\varepsilon)}{\Gamma^2(\frac{D}{2})(4\pi)^D}\Bigg(\frac{m_1^2}{m_1^{4\varepsilon}}\int dx x^{-\varepsilon}(1-x)^{\varepsilon} \\
&\quad \left(F(\varepsilon,2\varepsilon;1+\varepsilon;1-\frac{x_{51}}{x}-\frac{x_{61}}{1-x})-F(\varepsilon,2\varepsilon;1+\varepsilon;1-\frac{x_{51}}{x}-\frac{x_{71}}{1-x})\right)-(m_1^2\to m_2^2)\Bigg) \qquad (12)
\end{aligned}$$

with $x_{ij}=\frac{m_i^2}{m_j^2}$. $F(\alpha,\beta;\gamma;t)$ is the hypergeometric function [34] and $\varepsilon = 2-\frac{D}{2}$. To derive Eq.12, we employ formula[35]

$$\int_0^\infty dt t^{\lambda-1}(1+t)^{-\mu+\nu}(t+\beta)^{-\nu} = B(\mu-\lambda,\lambda)F(\nu,\mu-\lambda;\mu;1-\beta) \qquad (13)$$

with $Re\mu > Re\lambda > 0$. Using the definition of the hypergeometric function[34, 35]

$$\begin{aligned}
F(\alpha,\beta;\gamma;z) &= 1+\frac{\alpha\cdot\beta}{\gamma\cdot 1}z+\frac{\alpha(\alpha+1)\beta(\beta+1)}{\gamma(\gamma+1)\cdot 1\cdot 2}z^2 \\
&\quad +\frac{\alpha(\alpha+1)(\alpha+2)\beta(\beta+1)(\beta+2)}{\gamma(\gamma+1)(\gamma+2)\cdot 1\cdot 2\cdot 3}z^3+\cdots, \qquad (14)
\end{aligned}$$

we have

$$\begin{aligned}
F(\varepsilon,2\varepsilon;1+\varepsilon;z) &= 1+\frac{2\varepsilon^2}{1\cdot 1}z+\frac{2\varepsilon^2\cdot 1\cdot 1}{(1\cdot 2)(1\cdot 2)}z^2+\frac{2\varepsilon^2(1\cdot 2)(1\cdot 2)}{(1\cdot 2\cdot 3)(1\cdot 2\cdot 3)}z^3 \\
&\quad +\cdots+\frac{2\varepsilon^2(n-1)!(n-1)!}{n!n!}z^n+\cdots \\
&= 1+2\varepsilon^2\int_0^2 dz\left(1+\frac{1\cdot 1}{2\cdot 1}z+\frac{(1\cdot 2)(1\cdot 2)}{2\cdot 3\ \ 2!}z^2+\cdots+\frac{(n-1)!(n-1)!}{n!(n-1)!}z^{n-1}+\cdots\right)+\cdots \\
&= 1+2\varepsilon^2\int_0^z dz F(1,1;2;z)+\cdots \\
&= 1+2\varepsilon^2 L_{i_2}(z)+\cdots \quad . \qquad (15)
\end{aligned}$$

This is the key formula to proceed our computation and $L_{i_2}(z)$ is the dilogarithm function, which is defined as

$$L_{i_2}(z) = -\int\limits_0^z dt \frac{\ln(1-t)}{t} = \sum_{n=1}^{\infty} \frac{z^n}{n^2}, \qquad |z| < 1. \tag{16}$$

Using Eq.15, we have

$$\begin{aligned} I^{a,1}_{(d),2} = \frac{1}{4\pi^4} \frac{1}{(m_1^2 - m_2^2)(m_6^2 - m_7^2)} \bigg(& m_1^2 \Big(\mathcal{S}L_{i_2}(x_{51}, x_{61}) - \mathcal{S}L_{i_2}(x_{51}, x_{71}) \Big) \\ & - m_2^2 \Big(\mathcal{S}L_{i_2}(x_{51}, x_{61}) - \mathcal{S}L_{i_2}(x_{51}, x_{71}) \Big) \bigg) \end{aligned} \tag{17}$$

and $\mathcal{S}L_{i_2}(a,b)$ is

$$\mathcal{S}L_{i_2}(a,b) = \int_0^1 dt L_{i_2}(1 - \frac{a}{t} - \frac{b}{1-t}),$$

which is a continuous and analytic function[36], whose general expression can be found in Appendix.C. In the above example, $I^{a,1}_{(d),2}$ does not contain divergence. Now, let us look at another part that contains ultraviolet divergence. In the same diagram Fig.7(d), there exists $I^{d}_{(d),2}$ which is ultraviolet divergent, the corresponding integral is

$$\begin{aligned} I^{d}_{(d),2} &= \int \frac{d^D k}{(2\pi)^D} \frac{d^D q}{(2\pi)^D} \frac{k^2 q^2}{(k^2 - m_1^2)(k^2 - m_2^2)(k^2 - m_3^2)(k^2 - m_4^2)((k+q)^2 - m_5^2)(q^2 - m_6^2)(q^2 - m_7^2)} \\ &= I^{d,1}_{(d),2} + m_7^2 I^{a}_{(d),1} + m_4^2 I^{b}_{(d),1} - m_4^2 m_7^2 I_{(d),0}. \end{aligned} \tag{18}$$

The explicit forms of $I^{d,1}_{(d),2}$, $I^{a,1}_{(d),1}$, $I^{b,1}_{(d),1}$, $I^{c,1}_{(d),2}$, $I_{(d),0}$, are given in Appendix.B. For convenience, we calculate only one of them as an example to display how to deal with them and obtain corresponding result. In the above expression, the form of $I^{d,1}_{(d),2}$ is

$$I^{d,1}_{(d),2} = \int \frac{d^D k}{(2\pi)^D} \frac{d^D q}{(2\pi)^D} \frac{1}{(k^2 - m_1^2)(k^2 - m_2^2)(k^2 - m_3^2)((k+q)^2 - m_5^2)(q^2 - m_6^2)}. \tag{19}$$

Explicitly, we have a solution

$$\begin{aligned} I^{d,1}_{(d),2} = \frac{1}{(4\pi)^4} \sum_{i=1}^{3} \frac{m_i^2}{\prod\limits_{j\neq i} (m_j^2 - m_i^2)} \bigg(& \Big(\frac{1}{\varepsilon} - \gamma_E + \ln 4\pi \Big) \ln x_{i\mathrm{w}} + \Big(3 - \gamma_E + \ln 4\pi \Big) \ln x_{i\mathrm{w}} \\ & - \ln^2 x_{i\mathrm{w}} - \mathcal{S}L_{i_2}(x_{5i}, x_{6i}) \bigg). \end{aligned} \tag{20}$$

Generally, in the self-energy (class Fig.7(c)) and vertex (class Fig.7(d)) insertion diagrams, there is ultraviolet divergence which needs to be renormalized; in the other topological classes (Fig.7(a, b, e)), no ultraviolet

divergence exists. Certain renormalization procedures can eliminate the ultraviolet divergence, here we employ the $\overline{\mathrm{MS}}$ (the modified minimal subtraction scheme) to do the job.

Now let us turn to possible infrared divergence which may occur in the integrations.

We expand the two-loop results with respect to m_b, m_d to order $\mathcal{O}(m_{b,d})$ and then let the masses of the down-type quarks (d, s and b) approach to zero. Explicitly, $\mathcal{S}L_{i_2}(a,b)$ is written as

$$\begin{aligned}\mathcal{S}L_{i_2}(a,b) =& \Big(3-\frac{\pi^2}{6}-\ln a\ln(1-a)+a\ln a\ln\frac{a-1}{a}-aL_{i_2}(\frac{1}{a})-L_{i_2}(a)\Big)\\ &+\frac{b}{a-1}\Big(a\Big(\frac{-\pi^2}{6}+\ln(a(1-a))\ln\frac{a-1}{a}+L_{i_2}(\frac{a}{a-1})-L_{i_2}(\frac{1}{a})+L_{i_2}(\frac{1}{1-a})\Big)\\ &-\Big(\ln a\ln b-L_{i_2}(a)-\frac{1}{2}\ln^2 a-\ln(a(1-a))\Big)\Big)+\mathcal{O}(b^2)\end{aligned} \tag{21}$$

with $b\to 0$. Obviously, Eq.(21) indicates that as $m_b\sim m_d=0$, $I^{a,b,c,d,e,f}_{(a),2}$, $I^{a,b,c}_{(a),1}$ and $I^{a,b,c,d,e,f}_{(b),2}$, $I^{a,b,c}_{(b),1}$ would blow up, however the superficial infrared divergence is benign as long as we retain the masses of the down-type quarks to be non-zero.

As discussed above, the QCD correction to the effective Hamiltonian of Eq.5 is given as follows

$$\Delta H_{eff}=\frac{G_F^2}{4\pi^2}m_{\mathrm{w}}^2\frac{\alpha_s}{4\pi}\sum_{i,j}\lambda_i\lambda_j U_{i,j}, \tag{22}$$

where

$$U_{i,j}=\sum_k^8\phi_k\mathcal{O}_k, \tag{23}$$

with $\mathcal{O}_k$ being defined in Eq.6 and ϕ_k are written as

$$\phi_k=\phi_k^g+\phi_k^{\tilde g}. \tag{24}$$

ϕ_k^g (k=1, 2, $\cdots$, 8) are the contributions of gluon and $\phi_k^{\tilde g}$ come from gluino corrections. ϕ_k^g have been derived and are of following forms

$$\begin{aligned}\phi_1^g =& L^1_{i,j}-\xi\Big(\frac{10}{3}S_1+\frac{1}{6}S_4+\frac{1}{6}S_7\Big)-\frac{10}{3}(1-\xi)\frac{x_{\mathrm{dw}}\ln x_{\mathrm{dw}}-x_{\mathrm{bw}}\ln x_{\mathrm{bw}}}{x_{\mathrm{dw}}-x_{\mathrm{bw}}}S_1\\ &+(\frac{4}{3}-\frac{1}{3}\xi)\ln x_{\mathrm{dw}}x_{\mathrm{bw}}S_1+\frac{8}{3}(1-\xi)\ln x_\mu S_1-(4-\xi)S_2\frac{m_bm_d}{2(m_d^2-m_b^2)}\ln\frac{x_{\mathrm{dw}}}{x_{\mathrm{bw}}}\\ &+2\ln x_\mu(\nabla_x S_1),\\ \phi_2^g =& L^2_{i,j}-\frac{11}{3}\xi S_2+(-\frac{25}{3}+\frac{10}{3}\xi)S_2\frac{x_{\mathrm{dw}}\ln x_{\mathrm{dw}}-x_{\mathrm{bw}}\ln x_{\mathrm{bw}}}{x_{\mathrm{dw}}-x_{\mathrm{bw}}}+\frac{1}{2}(2-\xi)S_2\ln x_{\mathrm{bw}}x_{\mathrm{dw}}\end{aligned}$$

$$
\begin{aligned}
&+(4-\xi)\Big(\frac{5}{6}S_1-\frac{5}{12}S_4+\frac{5}{6}S_6-\frac{5}{12}S_7\Big)\frac{m_b m_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}}\\
&+\frac{8}{3}(1-\xi)\ln x_\mu S_2+2\ln x_\mu(\nabla_x S_2),\\
\phi_3^g=&\ L_{i,j}^3+\frac{22}{3}\xi S_2+(\frac{50}{3}-\frac{20}{3}\xi)\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}+(2-\xi)S_2\ln x_{d\mathrm{w}}x_{b\mathrm{w}}\\
&-(4-\xi)\Big(\frac{5}{3}S_1-\frac{5}{6}S_4+\frac{5}{3}S_6-\frac{5}{6}S_7\Big)\frac{m_b m_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}}\\
&-\frac{16}{3}(1-\xi)\ln x_\mu S_2-4\ln x_\mu(\nabla_x S_2),\\
\phi_4^g=&\ L_{i,j}^4+\xi(\frac{1}{3}S_1-\frac{10}{3}S_4-\frac{1}{3}S_6)+(-\frac{4}{3}+\frac{10}{3}\xi)S_4\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\\
&+\frac{2-\xi}{3}S_4\ln x_{d\mathrm{w}}x_{b\mathrm{w}}+\frac{5}{6}(4-\xi)S_2\frac{m_b m_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}}\\
&+\frac{8}{3}(1-\xi)\ln x_\mu S_4+2\ln x_\mu(\nabla_x S_4),\\
\phi_5^g=&\ L_{i,j}^5+\xi(\frac{1}{12}S_1-\frac{5}{6}S_4-\frac{1}{12}S_6)+(-\frac{1}{3}+\frac{5}{6}\xi)S_4\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\\
&+\frac{2-\xi}{12}S_4\ln x_{d\mathrm{w}}x_{b\mathrm{w}}+\frac{5}{24}(4-\xi)S_2\frac{m_b m_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}}\\
&+\frac{2}{3}(1-\xi)\ln x_\mu S_4+\frac{1}{2}\ln x_\mu(\nabla_x S_4),\\
\phi_6^g=&\ L_{i,j}^6-\xi\Big(\frac{10}{3}S_6+\frac{1}{6}S_4+\frac{1}{6}S_7\Big)-\frac{10}{3}(1-\xi)\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}S_6\\
&+(\frac{4}{3}-\frac{1}{3}\xi)\ln x_{d\mathrm{w}}x_{b\mathrm{w}}S_6+\frac{8}{3}(1-\xi)\ln x_\mu S_6-(4-\xi)S_2\frac{m_b m_d}{2(m_d^2-m_b^2)}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}}\\
&+2\ln x_\mu(\nabla_x S_6),\\
\phi_7^g=&\ L_{i,j}^7+\xi(\frac{1}{3}S_6-\frac{10}{3}S_7-\frac{1}{3}S_1)+(-\frac{4}{3}+\frac{10}{3}\xi)S_7\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\\
&+\frac{2-\xi}{3}S_7\ln x_{d\mathrm{w}}x_{b\mathrm{w}}+\frac{5}{6}(4-\xi)S_2\frac{m_b m_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}}\\
&+\frac{8}{3}(1-\xi)\ln x_\mu S_7+2\ln x_\mu(\nabla_x S_7),\\
\phi_8^g=&\ L_{i,j}^8+\xi(\frac{1}{12}S_6-\frac{5}{6}S_7-\frac{1}{12}S_1)+(-\frac{1}{3}+\frac{5}{6}\xi)S_7\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\\
&+\frac{2-\xi}{12}S_7\ln x_{d\mathrm{w}}x_{b\mathrm{w}}+\frac{5}{24}(4-\xi)S_2\frac{m_b m_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}}\\
&+\frac{2}{3}(1-\xi)\ln x_\mu S_7+\frac{1}{2}\ln x_\mu(\nabla_x S_7),
\end{aligned}
\tag{25}
$$

where $x_\mu = \frac{\mu^2}{m_{\rm w}^2}$ and μ is the scale at which the heavy degrees of freedom are integrated out.

It is noted that there are $\log x_i$ terms in the expressions. In fact, the situation for the Feynman diagrams including the vertex and self-energy insertions is more subtle, because these kinds of diagrams are logarithmically divergent. When the masses of the inner loop (vertex loop or self-energy) are much greater than that of the outer loop, [2] logarithmic divergence $\log \frac{m_i^2}{m_e^2}$ may emerge where m_i is the mass of the particles in the inner loop (vertex correction or self-energy) and m_e is the mass of particles in the outer loop [45].

Here, we have defined a new symbol

$$\nabla_x = 3x_{i{\rm w}}\frac{\partial}{\partial x_{i{\rm w}}} + 3x_{j{\rm w}}\frac{\partial}{\partial x_{j{\rm w}}}2x_{H_k^-{\rm w}}\frac{\partial}{\partial x_{H_k^-{\rm w}}} + +2x_{H_l^-{\rm w}}\frac{\partial}{\partial x_{H_l^-{\rm w}}} + 3x_{\tilde{\kappa}_k^-{\rm w}}\frac{\partial}{\partial x_{\tilde{\kappa}_k^-{\rm w}}}$$
$$+3x_{\tilde{\kappa}_l^-{\rm w}}\frac{\partial}{\partial x_{\tilde{\kappa}_l^-{\rm w}}} + 2x_{\tilde{U^i}_m{\rm w}}\frac{\partial}{\partial x_{\tilde{U^i}_m{\rm w}}} + 2x_{\tilde{U^i}_n{\rm w}}\frac{\partial}{\partial x_{\tilde{U^i}_n{\rm w}}}. \tag{26}$$

One should note that all the masses entering the functions are the masses evaluated at the μ scale. $L_{i,j}^a$ $(a = 1, \cdot, 8)$ are complicated functions of inner line masses, which are collected in the appendix. When we derive the above results, the Fierz-transformation is used to organize the emerging operators into the form of color-singlet current$\otimes$color-singlet current. As for the diagrams contain the ultraviolet divergence, we have taken the $\mathcal{O}(\varepsilon)$ contributions into account seriously. The results depend on the gauge parameter, and are infrared-divergent as $m_{b,d} \to 0$. However, the infrared divergence and gauge-dependence vanish after we match the full and effective sides of the theory and the explicit procedure of the matching is shown in next subsection.

3.2 Wilson coefficient function of $\mathcal{O}_i$

The effective Hamiltonian to order $O(\alpha_s)$ is given as

$$H_{eff} = H_{eff}^0 + \Delta H_{eff}, \tag{27}$$

where H_{eff}^0 is the pure box contribution and ΔH_{eff} is the Hamiltonian resulted in by the SUSY-QCD corrections. To obtain the Wilson coefficients in Eq.(27), one needs to properly handle the matching condition between the full theory and effective one.

As stated above, the Hamiltonian contains the infrared divergence and gauge dependence. In order to obtain physics results, we need to match the effective theory to the full theory. Before doing this, we evaluate

[2] Here "inner loop" refers to the loop for the inserted self-energy and vertex corrections, whereas "outer loop" is for the loop part outside the "inner loop". These notations are taken to distinguish "inner" and "outer" from "internal" and "external" quantities in the loop evaluation to avoid possible ambiguities.

the matrix elements of the physical operators $\mathcal{O}_i(i=1,\ldots,8)$ up to order $O(\alpha_s)$ using the same regularization, renormalization and gauge prescriptions employed above. The one-loop diagrams which are responsible for the corrections to the operators $\mathcal{O}_i$ are given in Fig.8, the results are

$$\mathcal{O}_i=\mathcal{O}_i^{(0)}+\frac{\alpha_s}{4\pi^2}\sum_j\Big(C_F r_{ij}^{(1)}\mathcal{O}_j^{(1)}+T^a\otimes T^a r_{ij}^{(8)}\tilde{\mathcal{O}}_j^{(8)}\Big) \tag{28}$$

with

$$\begin{aligned}
r_{11}^{(1)} &= -3+2(1-\xi)\Big(1+\ln x_\mu-\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\Big),\\
r_{12}^{(1)} &= (4-\xi)\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},\\
r_{11}^{(8)} &= -5-(4-\xi)(2\ln x_\mu-\ln x_{d\mathrm{w}}x_{b\mathrm{w}})+2(1-\xi)\Big(1+\ln x_\mu-\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\Big),\\
r_{13}^{(8)} &= -2(4-\xi)\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},\\
r_{14}^{(8)} &= r_{17}^{(8)}=-(4-\xi);\\
r_{15}^{(8)} &= r_{18}^{(8)}=\frac{1}{4}(4-\xi);\\
r_{21}^{(1)} &= \frac{1}{2}(4-\xi)\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},\\
r_{22}^{(1)} &= -3+2(1-\xi)\Big(1+\ln x_\mu-\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\Big),\\
r_{26}^{(1)} &= \frac{1}{2}(4-\xi)\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},\\
r_{22}^{(8)} &= (4-\xi)\Big(\ln x_{d\mathrm{w}}x_{b\mathrm{w}}-2\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\Big)-8-2\xi,\\
r_{23}^{(8)} &= -2(4-\xi),\\
r_{24}^{(8)} &= r_{27}^{(8)}=-(4-\xi)\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},\\
r_{25}^{(8)} &= r_{28}^{(8)}=\frac{4-\xi}{4}\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},\\
r_{33}^{(1)} &= 4-2\xi+2(4-\xi)\Big(\ln x_\mu-\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}}-x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}}-x_{b\mathrm{w}}}\Big),\\
r_{34}^{(1)} &= r_{37}^{(1)}=-(4-\xi)\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},\\
r_{31}^{(8)} &= \frac{1}{4}(4-\xi)\frac{m_bm_d}{m_d^2-m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},
\end{aligned}$$

$$r_{32}^{(8)} = -\frac{1}{2}(4-\xi),$$

$$r_{33}^{(8)} = -\frac{5}{2} - 2\xi + 2(1-\xi)\Big(\ln x_{d\mathrm{w}} x_{b\mathrm{w}} - \frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}}\Big),$$

$$r_{36}^{(8)} = \frac{1}{4}(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{43}^{(1)} = -2(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{44}^{(1)} = 4 - 2\xi + 2(4-\xi)\Big(\ln x_\mu - \frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}}\Big),$$

$$r_{41}^{(8)} = -\frac{1}{4}(4-\xi),$$

$$r_{42}^{(8)} = -\frac{1}{2}(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{44}^{(8)} = (1-\xi)\Big(2 + \ln x_{d\mathrm{w}} x_{b\mathrm{w}} - 2\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}}\Big),$$

$$r_{45}^{(8)} = \frac{3}{4} - \ln x_\mu + \frac{1}{4}\ln x_{b\mathrm{w}} x_{d\mathrm{w}} + \frac{1}{2}\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}},$$

$$r_{46}^{(8)} = -\frac{1}{4}(4-\xi),$$

$$r_{55}^{(1)} = 2\xi\Big(\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}} - \ln x_\mu - 1\Big),$$

$$r_{51}^{(8)} = 3(4-\xi),$$

$$r_{52}^{(8)} = -24(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{54}^{(8)} = -32 + 48\ln x_\mu - 12\ln x_{d\mathrm{w}} x_{b\mathrm{w}} - 24\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}},$$

$$r_{55}^{(8)} = 2(3+\xi)\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}} - (3+\xi)\ln x_{d\mathrm{w}} x_{b\mathrm{w}} - 2(1+\xi),$$

$$r_{66}^{(1)} = -3 + 2(1-\xi)\Big(1 + \ln x_\mu - \frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}}\Big),$$

$$r_{62}^{(1)} = (4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{66}^{(8)} = -5 - (4-\xi)(2\ln x_\mu - \ln x_{d\mathrm{w}} x_{b\mathrm{w}}) + 2(1-\xi)\Big(1 + \ln x_\mu - \frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}}\Big),$$

$$r_{63}^{(8)} = -2(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{64}^{(8)} = r_{67}^{(8)} = -(4-\xi);$$

$$r_{65}^{(8)} = r_{68}^{(8)} = \frac{1}{4}(4-\xi),$$

$$r_{73}^{(1)} = -2(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{77}^{(1)} = 4 - 2\xi + 2(4-\xi)\Big(\ln x_\mu - \frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}}\Big),$$

$$r_{76}^{(8)} = -\frac{1}{4}(4-\xi),$$

$$r_{72}^{(8)} = -\frac{1}{2}(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{77}^{(8)} = (1-\xi)\Big(2 + \ln x_{d\mathrm{w}}x_{b\mathrm{w}} - 2\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}}\Big),$$

$$r_{78}^{(8)} = \frac{3}{4} - \ln x_\mu + \frac{1}{4}\ln x_{b\mathrm{w}}x_{d\mathrm{w}} + \frac{1}{2}\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}},$$

$$r_{71}^{(8)} = -\frac{1}{4}(4-\xi),$$

$$r_{88}^{(1)} = 2\xi\Big(\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}} - \ln x_\mu - 1\Big),$$

$$r_{86}^{(8)} = 3(4-\xi),$$

$$r_{82}^{(8)} = -24(4-\xi)\frac{m_b m_d}{m_d^2 - m_b^2}\ln\frac{x_{d\mathrm{w}}}{x_{b\mathrm{w}}},$$

$$r_{87}^{(8)} = -32 + 48\ln x_\mu - 12\ln x_{d\mathrm{w}}x_{b\mathrm{w}} - 24\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}},$$

$$r_{88}^{(8)} = 2(3+\xi)\frac{x_{d\mathrm{w}}\ln x_{d\mathrm{w}} - x_{b\mathrm{w}}\ln x_{b\mathrm{w}}}{x_{d\mathrm{w}} - x_{b\mathrm{w}}} - (3+\xi)\ln x_{d\mathrm{w}}x_{b\mathrm{w}} - 2(1+\xi). \tag{29}$$

The other elements of $r^{(1,8)}$ are zero. At the scale μ where matching between the full Hamiltonian and the effective one is made, the matching condition can be written as

$$\begin{aligned} H_{eff} &= H_{eff}^0 + \Delta H_{eff} \\ &\equiv H_{full} = \frac{G_F^2}{4\pi^2}\lambda_i\lambda_j\Big(\vec{\mathcal{O}}^{(0)T}\cdot[\vec{S} + \frac{\alpha_s}{4\pi}\vec{\phi}]\Big) \\ &= \frac{G_F^2}{4\pi^2}\lambda_i\lambda_j\vec{\mathcal{O}}^T(\mu)\cdot\vec{C}(\mu) \end{aligned} \tag{30}$$

where $\vec{\mathcal{O}}^{(0)}$ are the tree-level operators, but $\vec{\mathcal{O}}(\mu)$ are the QCD-modified operators and $\vec{C}(\mu)$ are the corresponding coefficients. From the Eq.28 and Eq.29, we obtain

$$\vec{\mathcal{O}}(\mu) = \Big(1 + \frac{\alpha_s}{4\pi}\hat{r}\Big)\vec{\mathcal{O}}^{(0)}, \tag{31}$$

where matrix $\hat{r}$ can be obtained from $r^{(1)}$, $r^{(8)}$ and is read as

$$\hat{r} = \frac{1}{2}\Big[C_F r^{(1)} + \frac{1}{2} r^{(8)} \cdot \mathcal{F} - \frac{1}{6} r^{(8)}\Big] \cdot \Big(\hat{I} + \mathcal{F}\Big), \tag{32}$$

where $\hat{I}$ denotes the unit matrix and $\mathcal{F}$ is the Fierz transformation matrix in the basis Eq.6:

$$\mathcal{F} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -2 & 0 & 0 & 0 & 0 & 0 \\ 0 & -\frac{1}{2} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -\frac{1}{2} & \frac{1}{8} & 0 & 0 & 0 \\ 0 & 0 & 0 & 6 & \frac{1}{2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -\frac{1}{2} & \frac{1}{8} \\ 0 & 0 & 0 & 0 & 0 & 0 & 6 & \frac{1}{2} \end{pmatrix} \tag{33}$$

The coefficients $\vec{C}(\mu)$ are obtained by comparing Eq.30 with Eq.31[37]:

$$\vec{C}(\mu) = \vec{S} + \frac{\alpha_s}{4\pi}\Big(\vec{\phi} - \hat{r}^T \vec{S}\Big) \tag{34}$$

where $\vec{C}(\mu)$ are given as

$$\begin{aligned}
C_1(\mu) &= S_1 + \frac{\alpha_s}{4\pi}\Big[\phi^{\tilde{g},1}_{i,j} + L^1_{i,j} + C_F\Big(S_1 + 2\ln x_\mu S_1 + 2\ln x_\mu \nabla_x S_1\Big) \\
&\quad + C_A\Big((3 + 6\ln x_\mu) S_1 + 4(S_4 + S_5) - (S_7 + S_8)\Big)\Big], \\
C_2(\mu) &= S_2 + \frac{\alpha_s}{4\pi}\Big[\phi^{\tilde{g},2}_{i,j} + L^2_{i,j} + C_F\Big(-\frac{1}{2} S_2 - 4\ln x_\mu S_2 + 2\ln x_\mu \nabla_x S_2\Big) \\
&\quad + \frac{13}{12} S_2\Big], \\
C_3(\mu) &= S_3 + \frac{\alpha_s}{4\pi}\Big[\phi^{\tilde{g},3}_{i,j} + L^3_{i,j} + C_F\Big(S_2 + 8\ln x_\mu S_2 + 2\ln x_\mu \nabla_x S_3\Big) \\
&\quad - \frac{13}{6} S_2\Big], \\
C_4(\mu) &= S_4 + \frac{\alpha_s}{4\pi}\Big[\phi^{\tilde{g},4}_{i,j} + L^4_{i,j} + C_F\Big(-12 S_4 - 24\ln x_\mu S_4 + 2\ln x_\mu \nabla_x S_4\Big) \\
&\quad - \frac{143}{12} S_1 + \frac{191}{6} S_4 + \frac{31}{16} S_5 + \frac{1}{12} S_6 - 24\ln x_\mu S_4 + \frac{1}{12}\ln x_\mu S_5\Big], \\
C_5(\mu) &= S_5 + \frac{\alpha_s}{4\pi}\Big[\phi^{\tilde{g},5}_{i,j} + L^5_{i,j} + C_F\Big(-12 S_5 - 24\ln x_\mu S_5 + 2\ln x_\mu \nabla_x S_5\Big) \\
&\quad - \frac{143}{48} S_1 + \frac{191}{24} S_4 + \frac{31}{64} S_5 + \frac{1}{48} S_6 - 6\ln x_\mu S_4 + \frac{1}{48}\ln x_\mu S_5\Big], \\
C_6(\mu) &= S_6 + \frac{\alpha_s}{4\pi}\Big[\phi^{\tilde{g},6}_{i,j} + L^6_{i,j}\Big(S_6 + 2\ln x_\mu S_6 + 2\ln x_\mu \nabla_x S_6\Big) \\
&\quad + C_A\Big((3 + 6\ln x_\mu) S_6 + 4(S_7 + S_8) - (S_4 + S_5)\Big)\Big],
\end{aligned}$$

$$
\begin{aligned}
C_7(\mu) &= S_7 + \frac{\alpha_s}{4\pi}\Big[\phi_{i,j}^{\tilde{g},7} + L_{i,j}^7 + C_F\Big(- 12S_7 - 24\ln x_\mu S_7 + 2\ln x_\mu \nabla_x S_7\Big) \\
&\quad -\frac{143}{12}S_6 + \frac{191}{6}S_7 + \frac{31}{16}S_8 + \frac{1}{12}S_1 - 24\ln x_\mu S_7 + \frac{1}{12}\ln x_\mu S_8\Big], \\
C_8(\mu) &= S_8 + \frac{\alpha_s}{4\pi}\Big[\phi_{i,j}^{\tilde{g},8} + L_{i,j}^8 + C_F\Big(- 12S_8 - 24\ln x_\mu S_8 + 2\ln x_\mu \nabla_x S_8\Big) \\
&\quad -\frac{143}{48}S_6 + \frac{191}{24}S_7 + \frac{31}{64}S_8 + \frac{1}{48}S_1 - 6\ln x_\mu S_7 + \frac{1}{48}\ln x_\mu S_8\Big],
\end{aligned} \tag{35}
$$

with $C_F = \frac{4}{3}$, $C_A = \frac{1}{3}$, and S_1 through S_8 are defined in Eq.(7). Hence, at this stage we have the expressions for the Wilson- coefficients at the matching scale μ, which do not suffer from the infrared divergence under limit of $m_b \sim m_d = 0$, and this is consistent with the requirements for the effective Hamiltonian. The next step is to perform an evolution down to lower scales. The renormalization group equation for the Wilson coefficients $\vec{\mathcal{C}}$ reads

$$
\Big[\mu\frac{\partial}{\partial\mu} + \beta(\alpha_s)\frac{\partial}{\partial\alpha_s} - \frac{\hat{\gamma}^T}{2}\Big]\vec{C}(\mu,\alpha_s) = 0 \tag{36}
$$

where $\hat{\gamma}$ is the anomalous-dimension matrix and $\beta(\alpha_s)$ is the usual β function. The solution of the Eq.36 is discussed in [37] and we only cite the result here. Through the renormalization-group evolution matrix $\hat{\mathrm{W}}(m,\mu)$, the vectors $\vec{C}(m)$ can be written as

$$
\vec{C}(m) = \hat{\mathrm{W}}(m,\mu)\vec{C}(\mu) \tag{37}
$$

with

$$
\hat{\mathrm{W}}(m,\mu) = \Big(1 + \frac{\alpha_s(m)}{4\pi}\hat{J}(m)\Big)U(\hat{m,\mu})\Big(1 + \frac{\alpha_s(\mu)}{4\pi}\hat{J}(\mu)\Big)^{-1}, \tag{38}
$$

where $\hat{U}$ is the leading-order evolution matrix

$$
\hat{U}(m,\mu) = \Big[\frac{\alpha_s(\mu)}{\alpha_s(m)}\Big]^{\hat{\gamma}^{0T}/2\beta_0} \tag{39}
$$

and the matrix $\hat{J}$ is given in [37]. To obtain the above formulae, the computer algebra system MATHEMATICA 4.0[42] and MATHEMATICA-based package FeynArts[43] are used. The package TRACER[44] is used to evaluate the spinor structure.

The main purpose of this work is investigating the gluino corrections to the $B^0 - \overline{B}^0$ mixing in the supersymmetric scenario with minimal flavor violation. Before proceeding our discussion, we would analyze the gluino corrections to ΔH_{eff} first. In order to understand the point thoroughly, we neglect the mixing between the right- and left- squarks. In the case, $\mathcal{Z}_{\tilde{Q}^i}^{12} = \mathcal{Z}_{\tilde{Q}^i}^{21} = 0$, $\mathcal{Z}_{\tilde{Q}^i}^{11} = \mathcal{Z}_{\tilde{Q}^i}^{22} = 1$ and $m_{\tilde{Q}_1^i} = m_{\tilde{Q}_R^i}$,

$m_{\tilde{Q}_2^i} = m_{\tilde{Q}_L^i}$. In the computation of corrections from gluinos to $B^0 - \overline{B}^0$ mixing, the following terms will appear in the coefficients of $Q_1(\mu)$ (Fig.6(g,h))

$$C_1(\mu) \propto -i\frac{G_F^2}{4\pi^2}m_{\rm w}^2\frac{\alpha_s}{4\pi}\lambda_t\lambda_t^*\Big\{2C_F\sum_{\alpha\beta}\mathcal{Z}_{\tilde{D}^3}^{1\alpha}\mathcal{Z}_{\tilde{D}^3}^{1\alpha*}\mathcal{Z}_{\tilde{U}^3}^{1\beta}\mathcal{Z}_{\tilde{U}^3}^{1\beta*}\Big[F_D^{2e} - F_D^{2a}$$
$$-F_D^{2d}\Big](x_1, x_2, x_3, x_4, x_{\tilde{D}_\alpha^3}, x_{\tilde{g}{\rm w}}, x_{\tilde{U}_\beta^3})\Big\}, \tag{40}$$

where x_i $(i = 1, 2)$ represent $x_{u^I{\rm w}}$ (I=1, 2, 3) and x_k $(k = 3, 4)$ represent $x_{H_l^-{\rm w}}$ $(l = 1, 2)$. When $x_{\tilde{g}} \gg x_{\tilde{D}_\alpha^3}, x_{\tilde{U}_\beta^3}$, we have

$$C_1(\mu) \propto i\frac{G_F^2}{4\pi^2}m_{\rm w}^2\frac{\alpha_s}{4\pi}\lambda_t\lambda_t^*\Big[2C_F\sum_{i=1}^{4}\frac{x_{i{\rm w}}^2\ln x_{i{\rm w}}}{\prod\limits_{j\neq i}(x_{j{\rm w}} - x_{i{\rm w}})}\Big]\ln x_{\tilde{g}{\rm w}}$$
$$= i\frac{G_F^2}{4\pi^2}m_{\rm w}^2\frac{\alpha_s}{4\pi}\lambda_t\lambda_t^*\Big[\frac{2x_{t{\rm w}}\ln x_{t{\rm w}}}{(x_{t{\rm w}} - 1)^3} - \frac{1 + x_{t{\rm w}}}{(x_{t{\rm w}} - 1)^2}\Big]\ln x_{\tilde{g}{\rm w}} \tag{41}$$

Here, we have presumed $\tan\beta \sim 1$ and the contributions to other $C_i(\mu)$ $(i = 2, \cdots, 8)$ are suppressed by the small Yukawa couplings h_b, h_d. In Eq.41, we have set $x_1 = x_2 = x_{t{\rm w}}$ and $x_3 = x_4 = 1$ (this choice corresponds to exchanging W-boson and top quark in the outer loop). Similar analysis can be performed in calculating the contributions of Fig.5(e,f) (self-insertion diagrams), and we will find the amplitude growing with $\ln x_{\tilde{g}{\rm w}}$ when $m_{\tilde{g}} \gg m_{\tilde{U}_1^3}$. A similar conclusion is derived in the SM, where the one-loop radiation corrections to mass of the W-boson is increasing with $\ln m_h$ (m_h is the mass of the standard Higgs)[41]. When $\tan\beta \gg 1$, the corrections to the coefficients $C_i(\mu)$ $(i = 2, \cdots, 8)$ must be taken into account seriously, because those terms cannot cancel each other among themselves and are enhanced strongly when the mass of gluino $m_{\tilde{g}}$ is much greater than $m_{\tilde{U}_1^3}$. If we consider the mixing between the left- and right-squarks, the expressions would be very complicated and we present them in the appendix. We will further discuss the gluino corrections in the section of numerical results. However, for illustration of the physics picture, neglecting such mixing would not bring up any confusion.

3.3 Hadronic Matrix Elements

To numerically evaluate the $B^0 - \overline{B}^0$ ($K^0 - \overline{K}^0$) mixing, besides the low-energy effective $\Delta B = 2$ Lagrangian, one needs to properly calculate the hadronic matrix elements of the various operators in Eq.27. Estimation of such hadronic matrix elements is notoriously difficult, and is generally accompanied by large uncertainties due to long-distance, non-perturbative QCD effects. Fortunately, although the same case holds in the current

context, there are two factors which mitigate those hadronic uncertainties in our ensuring phenomenological analysis:

- The supersymmetric contributions to $\overline{B}^0 - B^0$ and $\overline{K}^0 - K^0$ mixing in the MSSM with minimal flavor violation give rise to the same operator $\mathcal{O}_1$ that exists in the standard model. This makes comparison of the supersymmetry and standard model contributions relatively straightforward.
- For the $\overline{B}^0 - B^0$ system, the vacuum saturation approximation employed below is believed to be a good approximation. This belief is supported by the lattice Monte Carlo estimates which give $B_B \simeq 1$[38, 39].

We begin by restating the conventional result for the operator $\mathcal{O}_1$:

$$< K^0|\mathcal{O}_1|\overline{K}^0 >= \frac{1}{3} f_k^2 m_K^2 B_K^1, \tag{42}$$

where $f_K \simeq 165$MeV is the K-meson decay constant and $B_K^1 = 1$ corresponds to the "vacuum saturation" result. Various estimates of this matrix element place B_K^1 in the range of $0.3 \sim 1$[40], with a value $B_K^1 \sim 0.7$ is favored by the lattice gauge results[38, 39]. Matrix elements of the other hadronic operators $\mathcal{O}_i$ $(i = 2, \cdots, 8)$ can be written as

$$\begin{aligned}
< K^0|\mathcal{O}_2|\overline{K}^0 >&= -\left[\frac{1}{4} - \frac{1}{6}\left(\frac{m_K}{m_s + m_d}\right)^2\right] m_K^2 f_K^2 B_K^2, \\
< K^0|\mathcal{O}_3|\overline{K}^0 >&= \left[\frac{1}{24} - \frac{1}{4}\left(\frac{m_K}{m_s + m_d}\right)^2\right] m_K^2 f_K^2 B_K^3, \\
< K^0|\mathcal{O}_4|\overline{K}^0 >&= \frac{5}{24}\left(\frac{m_K}{m_s + m_d}\right)^2 m_K^2 f_K^2 B_K^4, \\
< K^0|\mathcal{O}_5|\overline{K}^0 >&= \frac{1}{4}\left(\frac{m_K}{m_s + m_d}\right)^2 m_K^2 f_K^2 B_K^5, \\
< K^0|\mathcal{O}_6|\overline{K}^0 >&= \frac{1}{3} f_k^2 m_K^2 B_K^6, \\
< K^0|\mathcal{O}_7|\overline{K}^0 >&= \frac{5}{24}\left(\frac{m_K}{m_s + m_d}\right)^2 m_K^2 f_K^2 B_K^7, \\
< K^0|\mathcal{O}_8|\overline{K}^0 >&= \frac{1}{4}\left(\frac{m_K}{m_s + m_d}\right)^2 m_K^2 f_K^2 B_K^8.
\end{aligned} \tag{43}$$

Similarly, the factors B_K^i $(i = 2, \cdots, 8)$ are associated with each of the matrix elements in Eq.43.

The corresponding results for the $\Delta B = 2$ matrix elements are simplified by the fact that the current algebra enhancement factor $\frac{m_B}{m_b + m_d} \simeq 1$ is sufficiently accurate to present experimental tolerance. Thus we

have

$$
\begin{aligned}
< B^0|\mathcal{O}_1|\overline{B}^0 >&= \frac{1}{3}f_B^2 m_B^2,\\
< B^0|\mathcal{O}_2|\overline{B}^0 >&= -\frac{1}{12}f_B^2 m_B^2,\\
< B^0|\mathcal{O}_3|\overline{B}^0 >&= -\frac{5}{24}f_B^2 m_B^2,\\
< B^0|\mathcal{O}_4|\overline{B}^0 >&= \frac{5}{24}f_B^2 m_B^2,\\
< B^0|\mathcal{O}_5|\overline{B}^0 >&= \frac{1}{4}f_B^2 m_B^2,\\
< B^0|\mathcal{O}_6|\overline{B}^0 >&= \frac{1}{3}f_B^2 m_B^2,\\
< B^0|\mathcal{O}_7|\overline{B}^0 >&= \frac{5}{24}f_B^2 m_B^2,\\
< B^0|\mathcal{O}_8|\overline{B}^0 >&= \frac{1}{4}f_B^2 m_B^2,
\end{aligned}
\tag{44}
$$

However, the potential benefits gained by setting $B_B^i \simeq 1$ $(i = 1, \cdots, 8)$ for the $\overline{B}^0 - B^0$ matrix elements of Eq.44 are partially offset by our ignorance of f_B.

4 Numerical result

In this section, we will give the numerical discussions and compare our results with experimental data. Before presenting the numerical results, we list the input parameters that are used in our discussions. For the CKM matrix elements, we use the Wolfenstein-parametrization with parameters A, λ, ρ, η. The SM-parameters are set as: $G_F = 1.166 \times 10^{-5}\text{GeV}^{-2}$, $\alpha_s(m_{\rm w}) = 0.12$, $\alpha_s(m_b) = 0.22$, $\alpha_s(m_c) = 0.34$, $A = 0.80$, $\lambda = 0.22$, $m_b(m_{\rm w}) = 4.5\text{GeV}$, $m_c(m_{\rm w}) = 1.3\text{GeV}$, $m_t(m_{\rm w}) = 167\text{GeV}$, $f_B = 0.2\text{GeV}$, $f_K = 0.167\text{GeV}$. For parameters ρ, η, we have $\rho = 0.36$, $\eta = 0$. The factor B_K^i are chosen as $B_K^1 = B_K^2 = B_K^3 = B_K^4 = B_K^5 = B_K^6 = B_K^7 = B_K^8 = 0.7$. Using above parameters, the SM-predictions on Δm_B and Δm_K are

$$\Delta m_B(\text{SM}) = 2.18 \times 10^{-13}\text{GeV}, \Delta m_K(\text{SM}) = 2.89 \times 10^{-15}\text{GeV}.$$

At present, the experimental results are

$$\Delta m_B = (3.10 \pm 0.1) \times 10^{-13}\text{GeV}, \Delta m_K = (3.491 \pm 0.009) \times 10^{-15}\text{GeV}.$$

For the supersymmetric model with minimal flavor violation, the free parameters to be input are chosen as follows: $\tan\beta = \frac{\upsilon_2}{\upsilon_1}$, m_{H^-}, $m_{\kappa_\lambda^-}$, $m_{\tilde{U}_\alpha^i}$, $m_{\tilde{B}_\alpha}$, $m_{\tilde{D}_\alpha}$ $(\alpha, \lambda{=}1,\ 2)$ and the mixing matrix

$$\mathcal{Z}_{\tilde{U}^I} = \left(\begin{array}{cc} \cos\xi_{\tilde{U}^I} & \sin\xi_{\tilde{U}^I} \\ -\sin\xi_{\tilde{U}^I} & \cos\xi_{\tilde{U}^I} \end{array} \right), \tag{45}$$

$$\mathcal{Z}_{\tilde{B}} = \left(\begin{array}{cc} \cos\zeta_{\tilde{B}} & \sin\zeta_{\tilde{B}} \\ -\sin\zeta_{\tilde{B}} & \cos\zeta_{\tilde{B}} \end{array} \right), \tag{46}$$

$$\mathcal{Z}_{\tilde{D}} = \left(\begin{array}{cc} \cos\zeta_{\tilde{D}} & \sin\zeta_{\tilde{D}} \\ -\sin\zeta_{\tilde{D}} & \cos\zeta_{\tilde{D}} \end{array} \right). \tag{47}$$

As for the mixing matrices of charginos $\mathcal{Z}_\pm$, they can be fixed by the values of $\tan\beta$ and $m_{\kappa_i^-}$. In the numerical calculation, we assume that only one scalar quark is light and other heavy scalar quarks are taken as $m_{\tilde{D}_1} = 4.5$TeV, $m_{\tilde{B}_1} = 4.7$TeV, $m_{\tilde{D}_2} = 4.6$TeV, $m_{\tilde{B}_2} = 4.8$TeV, $m_{\tilde{U}_1^1} = 4.1$TeV, $m_{\tilde{U}_2^1} = 4.9$TeV, $m_{\tilde{U}_1^2} = 4.05$TeV, $m_{\tilde{U}_2^2} = 4.95$TeV and $m_{\tilde{U}_2^3} = 2.1$TeV. For the heavy chargino, we set $m_{\chi_2^-} = 2.2$TeV. In order to suppress the number of free parameters, we assume the mixing angles to be equal $\xi_{\tilde{U}^I} = \zeta_{\tilde{B}} = \zeta_{\tilde{D}}$ and focus on small value of $\tan\xi_{\tilde{U}^I}$.[3]

We obtain the dependence of Δm_B on the lighter scalar top quark mass with $m_{\chi_1^-} = 110$GeV, $m_{\tilde{g}} = 300$GeV, $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{D}} = \tan\zeta_{\tilde{B}} = 0$ and $\tan\beta = 1, 5, 30$. We find that as the lighter scalar top mass is greater than 300 GeV, the dependence is very mild, namely Δm_B almost does not change at all as $m_{\tilde{U}_1^3}$ increases further and results with and without the gluino contributions only deviate by a constant of about $0.3 \sim 1.0 \times 10^{-13}$ GeV depending on $\tan\beta$ value.

The dependence of Δm_B on the lighter chargino mass is similar to that on the lighter stop mass. With $m_{\tilde{U}_1^3} = 150$GeV, $m_{\tilde{g}} = 300$GeV, $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{D}} = \tan\zeta_{\tilde{B}} = 0$ and $\tan\beta = 1, 5, 30$, as the chargino mass is greater than 200 GeV, the dependence is very mild, namely Δm_B almost does not change at all as $m_{\chi_1^-}$ increases further and the results with and without the gluino contributions only deviate by a constant of $0.2 \sim 0.8 \times 10^{-13}$ GeV depending on the $\tan\beta$ value .

In Fig.9, we plot the dependence of Δm_B on gluino mass $m_{\tilde{g}}$ with $m_{\chi_1^-} = 110$ GeV, $m_{\tilde{U}_1^3} = 150$ GeV, $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{D}} = \tan\zeta_{\tilde{B}} = 0$ and $\tan\beta = 1, 5, 30$. We find that Δm_B more sensitively depends on the gluino mass. Obviously, the results including NLO corrections from gluino are closer to the data than that without gluino contributions. It is also noted that as $\tan\beta \sim 1$, the data favors heavier gluino, i.e. $m_{\tilde{g}}$ is greater than a few TeV's. But for $\tan\beta \geq 5$, the data favors $m_{\tilde{g}} \sim 400 \sim 600$ GeV and the dependence of Δm_B is no longer sensitive to $\tan\beta$.

[3]As free parameters, they can vary in the range $-\frac{\pi}{4} \leq \xi_{\tilde{U}^I}, \zeta_{\tilde{B}}, \zeta_{\tilde{D}} \leq \frac{\pi}{4}$

For the case that the mixing between left- and right- squarks is non-zero, we take $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{D}} = \tan\zeta_{\tilde{B}} = 0.1$ and plot Δm_B versus $m_{\tilde{g}}$ in Fig.10. The situation is very similar to the discussions given above.

Now, we turn to the $K^0 - \overline{K}^0$ mixing. In Fig.11, we plot the Δm_K versus the mass of gluino with other parameters being set as $m_{\chi_1^-} = 413$GeV, $m_{\tilde{U}_1^3} = 150$GeV, $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{D}} = \tan\zeta_{\tilde{B}} = 0$ and $\tan\beta = 1.5, 5, 30$ respectively. From these figures, we find that Δm_K is modified obviously when $m_{\tilde{g}}$ varies.

It is noted that we assumed $m_{\tilde{B}_1} \gg m_{\tilde{U}_1^3}$ in the above numerical computations, at present a possibility $m_{\tilde{B}_1} \sim m_{\tilde{U}_1^3}$ is widely considered. We have re-calculated the resultant dependence of Δm_B and Δm_K on the gluino mass with $m_{\tilde{B}_1} = m_{\tilde{U}_1^3} = 150$GeV as input. Our numerical results show that for smaller gluino mass of about 300 GeV, the changes from that with larger $m_{\tilde{B}_1}$ are very small and completely negligible. When the gluino mass turns larger, we find that the curves drop a bit faster. Concretely, as gluino mass reaches a region of about 3 TeV, the value of Δm_B is about 1.5% smaller than that with $m_{\tilde{B}_1} = 4.7$ TeV, and Δm_K is only suppressed by a factor of less than 1%.

From the above numerical analysis, we find that the gluino corrections cannot be neglected even when the gluino mass is very heavy. In the general case, the gluino mediated corrections depend on the choice of the parameter space and must be taken into account seriously.

5 Conclusions

We analyze the gluino mediated corrections to $B^0 - \overline{B}^0$ mixing systematically up to the Next-to-Leading Order in the supersymmetric extension of standard model with minimal flavor violation. In the general case, the gluino contributions are evident and cannot be neglected in the NLO QCD corrections. Our technique can be used in other rare B processes such as $b \to s\gamma$, $b \to sg$, $b \to sZ$ and $b \to se^+e^-$ in the total supersymmetric calculations. After the systematic analysis on the B- and K- systems, we can expect to extract some constraints on the supersymmetric parameter space.

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Appendix

A The functions in the one-loop calculations

The functions in the one loop integrals are

$$
\begin{aligned}
f_a(x_1,x_2,x_3,x_4) &= \sum_{i=1}^{4} \frac{x_i^2 \ln x_i}{\prod\limits_{j\neq i}(x_j-x_i)}, \\
f_b(x_1,x_2,x_3,x_4) &= \sum_{i=1}^{4} \frac{x_i \ln x_i}{\prod\limits_{j\neq i}(x_j-x_i)},
\end{aligned} \tag{48}
$$

when $x_3 = x_4 = 1$, they turn back to

$$
\begin{aligned}
f_a(x_1,x_2,1,1) &= \Big(\frac{x_1^2 \ln x_1}{(x_2-x_1)(1-x_1)^2} + \frac{x_2^2 \ln x_2}{(x_1-x_2)(1-x_2)^2} \\
&\quad + \frac{1}{(1-x_1)(1-x_2)}, \\
f_b(x_1,x_2,1,1) &= \Big(\frac{x_1 \ln x_1}{(x_2-x_1)(1-x_1)^2} + \frac{x_2 \ln x_2}{(x_1-x_2)(1-x_2)^2} \\
&\quad + \frac{1}{(1-x_1)(1-x_2)}.
\end{aligned} \tag{49}
$$

B The integrand functions of two loop

In this appendix, we give some necessary integrals that are used in the context. The five topological diagrams are drawn in Fig.7, the integrand functions are defined as

$$
\begin{aligned}
I_{(i),0}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) &= \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{1}{A_{(i)}} , \\
I^a_{(i),1}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) &= \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{k^2}{A_{(i)}} , \\
I^b_{(i),1}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) &= \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{q^2}{A_{(i)}} , \\
I^c_{(i),1}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) &= \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{(k+q)^2}{A_{(i)}} , \\
I^a_{(i),2}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) &= \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{k^4}{A_{(i)}} , \\
I^b_{(i),2}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) &= \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{q^4}{A_{(i)}} ,
\end{aligned}
$$

$$I^c_{(i),2}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{(k+q)^4}{A_{(i)}} \ ,$$

$$I^d_{(i),2}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{k^2q^2}{A_{(i)}} \ ,$$

$$I^e_{(i),2}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{k^2(k+q)^2}{A_{(i)}} \ ,$$

$$I^f_{(i),2}(m_1^2,m_2^2,m_3^2,m_4^2,m_5^2,m_6^2,m_7^2) = \int \frac{d^Dk}{(2\pi)^D}\frac{d^Dq}{2\pi)^D}\frac{(k+q)^2q^2}{A_{(i)}} \ , \tag{50}$$

where the definitions of $A_{(i)}$ are

$$A_{(a)} = (k^2-m_1^2)(k^2-m_2^2)(k^2-m_3^2)((k+q)^2-m_4^2)(q^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2),$$

$$A_{(b)} = (k^2-m_1^2)(k^2-m_2^2)((k+q)^2-m_3^2)((k+q)^2-m_4^2)(q^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2),$$

$$A_{(c)} = (k^2-m_1^2)(k^2-m_2^2)(k^2-m_3^2)(k^2-m_4^2)(k^2-m_5^2)((k+q)^2-m_6^2)(q^2-m_7^2),$$

$$A_{(d)} = (k^2-m_1^2)(k^2-m_2^2)(k^2-m_3^2)(k^2-m_4^2)((k+q)^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2),$$

$$A_{(e)} = (k^2-m_1^2)(k^2-m_2^2)(k^2-m_3^2)((k+q)^2-m_4^2)((k+q)^2-m_5^2)(q^2-m_6^2)(q^2-m_7^2). \tag{51}$$

Here, $i = a, b, c, d, e$ are the indices of the diagrams in Fig.7

The loop integrals for diagram A are decomposed as

$$I^a_{(a),2} = I^{a,1}_{(a),2} + (m_2^2+m_3^2)I^a_{(a),1} - m_2^2m_3^2I_{(a),0} \ ,$$

$$I^b_{(a),2} = I^{b,1}_{(a),2} + (m_6^2+m_7^2)I^b_{(a),1} - m_6^2m_7^2I_{(a),0} \ ,$$

$$I^c_{(a),2} = I^{c,1}_{(a),2} + m_4^2I^c_{(a),1} \ ,$$

$$I^d_{(a),2} = I^{d,1}_{(a),2} + m_3^2I^b_{(a),1} + m_7^2I^a_{(a),1} - m_3^2m_7^2I_{(a),0} \ ,$$

$$I^e_{(a),2} = I^{e,1}_{(a),2} + m_3^2I^c_{(a),1} + m_4^2I^a_{(a),1} - m_3^2m_4^2I_{(a),0} \ ,$$

$$I^f_{(a),2} = I^{f,1}_{(a),2} + m_4^2I^b_{(a),1} + m_7^2I^c_{(a),1} - m_4^2m_7^2I_{(a),0} \ ,$$

$$I^a_{(a),1} = I^{a,1}_{(a),1} + m_3^2I_{(a),0} \ ,$$

$$I^b_{(a),1} = I^{b,1}_{(a),1} + m_7^2I_{(a),0} \ ,$$

$$I^c_{(a),1} = I^{c,1}_{(a),1} + m_4^2I_{(a),0} \tag{52}$$

with

$$
\begin{aligned}
I^{a,1}_{(a),2} &= \frac{1}{(4\pi)^4}\sum_{\rho=5}^{7}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\ln x_{\rho\mu}\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)-\mathcal{S}L_{i_2}(x_{1\rho},x_{4\rho})\\
&\quad+\Big(3-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}\Big)\;,\\
I^{b,1}_{(a),2} &= \frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\ln x_{\rho\mu}\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)-\mathcal{S}L_{i_2}(x_{4\rho},x_{5\rho})\\
&\quad+\Big(3-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}\Big)\;,\\
I^{c,1}_{(a),2} &= \frac{1}{(4\pi)^4}\sum_{\rho_1=1}^{3}\sum_{\rho_2=5}^{7}\frac{m_{\rho_1}^4m_{\rho_2}^2+m_{\rho_1}^2m_{\rho_2}^4}{\prod\limits_{\sigma_1\neq\rho_1}(m_{\sigma_1}^2-m_{\rho_1}^2)\prod\limits_{\sigma_2\neq\rho_2}(m_{\sigma_2}^2-m_{\rho_2}^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho_1\mu}x_{\rho_2\mu})\\
&\quad+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho_1\mu}x_{\rho_2\mu})-\frac{1}{2}\ln^2(x_{\rho_1\mu}x_{\rho_2\mu})\Big)\;,\\
I^{d,1}_{(a),2} &= \frac{1}{m_5^2-m_6^2}\frac{1}{(4\pi)^2}\sum_{\rho=1}^{2}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{5\rho})-\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})\Big)\;,\\
I^{e,1}_{(a),2} &= \frac{1}{(4\pi)^4}\sum_{\rho_1=1}^{2}\sum_{\rho_2=5}^{7}\frac{m_{\rho_1}^2m_{\rho_2}^2}{\prod\limits_{\sigma_1\neq\rho_1}(m_{\sigma_1}^2-m_{\rho_1}^2)\prod\limits_{\sigma_2\neq\rho_2}(m_{\sigma_2}^2-m_{\rho_2}^2)}\Big(-\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho_1\mu}x_{\rho_2\mu})\\
&\quad-\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho_1\mu}x_{\rho_2\mu})+\frac{1}{2}\ln^2(x_{\rho_1\mu}x_{\rho_2\mu})\Big)\;,\\
I^{f,1}_{(a),2} &= \frac{1}{(4\pi)^4}\sum_{\rho_1=1}^{3}\sum_{\rho_2=5}^{6}\frac{m_{\rho_1}^2m_{\rho_2}^2}{\prod\limits_{\sigma_1\neq\rho_1}(m_{\sigma_1}^2-m_{\rho_1}^2)\prod\limits_{\sigma_2\neq\rho_2}(m_{\sigma_2}^2-m_{\rho_2}^2)}\Big(-\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho_1\mu}x_{\rho_2\mu})\\
&\quad-\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho_1\mu}x_{\rho_2\mu})+\frac{1}{2}\ln^2(x_{\rho_1\mu}x_{\rho_2\mu})\Big)\;,\\
I^{a,1}_{(a),1} &= -\frac{1}{m_1^2-m_2^2}\frac{1}{(4\pi)^4}\sum_{\rho=5}^{7}\frac{1}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(m_1^2\mathcal{S}L_{i_2}(x_{41},x_{\rho 1})-m_2^2\mathcal{S}L_{i_2}(x_{42},x_{\rho 2})\Big)\;,\\
I^{b,1}_{(a),1} &= -\frac{1}{m_5^2-m_6^2}\frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{5\rho})-\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})\Big)\;,\\
I^{c,1}_{(a),1} &= \frac{1}{2(4\pi)^4}\sum_{\rho_1=1}^{3}\sum_{\rho_2=5}^{7}\frac{m_{\rho_1}^2m_{\rho_2}^2}{\prod\limits_{\sigma_1\neq\rho_1}(m_{\sigma_1}^2-m_{\rho_1}^2)\prod\limits_{\sigma_2\neq\rho_2}(m_{\sigma_2}^2-m_{\rho_2}^2)}\ln^2(x_{\rho_1\mu}x_{\rho_2\mu})\;,\\
I_{(a),0} &= -\frac{1}{(4\pi)^4}\sum_{\rho_1=1}^{3}\sum_{\rho_2=5}^{7}\frac{m_{\rho_1}^2}{\prod\limits_{\sigma_1\neq\rho_1}(m_{\sigma_1}^2-m_{\rho_1}^2)\prod\limits_{\sigma_2\neq\rho_2}(m_{\sigma_2}^2-m_{\rho_2}^2)}\mathcal{S}L_{i_2}(x_{4\rho_1},x_{\rho_2\rho_1})\;. \qquad (53)
\end{aligned}
$$

For the diagrams of class B, the loop integrals are decomposed as

$$
\begin{aligned}
I^{a}_{(b),2} &= I^{a,1}_{(b),2} + (m_1^2 + m_2^2) I^{a}_{(b),1} - m_1^2 m_2^2 I_{(b),0}\;, \\
I^{b}_{(b),2} &= I^{b,1}_{(b),2} + (m_6^2 + m_7^2) I^{b}_{(b),1} - m_6^2 m_7^2 I_{(b),0}\;, \\
I^{c}_{(b),2} &= I^{c,1}_{(b),2} + (m_3^2 + m_4^2) I^{c}_{(b),1} - m_3^2 m_4^2 I_{(b),0}\;, \\
I^{d}_{(b),2} &= I^{d,1}_{(b),2} + m_2^2 I^{b}_{(b),1} + m_7^2 I^{a}_{(b),1} - m_2^2 m_7^2 I_{(b),0}\;, \\
I^{e}_{(b),2} &= I^{e,1}_{(b),2} + m_2^2 I^{c}_{(b),1} + m_4^2 I^{a}_{(b),1} - m_2^2 m_4^2 I_{(b),0}\;, \\
I^{f}_{(b),2} &= I^{f,1}_{(b),2} + m_4^2 I^{b}_{(b),1} + m_7^2 I^{c}_{(b),1} - m_4^2 m_7^2 I_{(b),0}\;, \\
I^{a}_{(b),1} &= I^{a,1}_{(b),1} + m_2^2 I_{(b),0}\;, \\
I^{b}_{(b),1} &= I^{b,1}_{(b),1} + m_7^2 I_{(b),0}\;, \\
I^{c}_{(b),1} &= I^{c,1}_{(b),1} + m_4^2 I_{(b),0}
\end{aligned}
\tag{54}
$$

and

$$
\begin{aligned}
I^{a,1}_{(b),2} &= \frac{1}{(4\pi)^4} \sum_{\rho=5}^{7} \frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho} (m_\sigma^2 - m_\rho^2)} \Big(\Big(\frac{1}{\varepsilon} - \gamma_E + \ln(4\pi)\Big) \ln x_{\rho\mu} + \Big(2 - \gamma_E + \ln 4\pi\Big) \ln x_{\rho\mu} \\
&\quad - \frac{m_3^2}{2(m_3^2 - m_4^2)} \ln^2(x_{3\mu} x_{\rho\mu}) + \frac{m_4^2}{2(m_3^2 - m_4^2)} \ln^2(x_{4\mu} x_{\rho\mu}) \Big)\;, \\
I^{b,1}_{(b),2} &= -\frac{1}{(4\pi)^4} \frac{1}{(m_1^2 - m_2^2)(m_3^2 - m_4^2)} \Big(m_1^2 \Big(\mathcal{S}L_{i_2}(x_{31}, x_{51}) - \mathcal{S}L_{i_2}(x_{41}, x_{51}) \Big) \\
&\quad - m_2^2 \Big(\mathcal{S}L_{i_2}(x_{32}, x_{52}) - \mathcal{S}L_{i_2}(x_{42}, x_{52}) \Big) \Big)\;, \\
I^{c,1}_{(b),2} &= \frac{1}{(4\pi)^4} \sum_{\rho=5}^{7} \frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho} (m_\sigma^2 - m_\rho^2)} \Big(\Big(\frac{1}{\varepsilon} - \gamma_E + \ln(4\pi)\Big) \ln x_{\rho\mu} + \Big(2 - \gamma_E + \ln 4\pi\Big) \ln x_{\rho\mu} \\
&\quad - \frac{m_1^2}{2(m_1^2 - m_2^2)} \ln^2(x_{1\mu} x_{\rho\mu}) + \frac{m_2^2}{2(m_1^2 - m_2^2)} \ln^2(x_{2\mu} x_{\rho\mu}) \Big)\;, \\
I^{d,1}_{(b),2} &= -\frac{1}{(4\pi)^4} \frac{1}{(m_3^2 - m_4^2)(m_5^2 - m_6^2)} \Big(m_5^2 \Big(\mathcal{S}L_{i_2}(x_{15}, x_{35}) - \mathcal{S}L_{i_2}(x_{15}, x_{45}) \Big) \\
&\quad - m_6^2 \Big(\mathcal{S}L_{i_2}(x_{16}, x_{36}) - \mathcal{S}L_{i_2}(x_{16}, x_{46}) \Big) \Big)\;, \\
I^{e,1}_{(b),2} &= \frac{1}{(4\pi)^4} \sum_{\rho=5}^{7} \frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho} (m_\sigma^2 - m_\rho^2)} \Big(\Big(\frac{1}{\varepsilon} - \gamma_E + \ln(4\pi)\Big) \ln x_{\rho\mu} + \Big(3 - \gamma_E + \ln 4\pi\Big) \ln x_{\rho\mu}
\end{aligned}
$$

$$
- \ln^2 x_{\rho\mu} - \mathcal{S}L_{i_2}(x_{1\rho}, x_{3\rho})\Big) ,
$$

$$
I^{f,1}_{(b),2} = -\frac{1}{(4\pi)^4}\frac{1}{(m_1^2-m_2^2)(m_5^2-m_6^2)}\Big(m_1^2\Big(\mathcal{S}L_{i_2}(x_{31},x_{51}) - \mathcal{S}L_{i_2}(x_{31},x_{61})\Big)
$$

$$
-m_2^2\Big(\mathcal{S}L_{i_2}(x_{32},x_{52}) - \mathcal{S}L_{i_2}(x_{32},x_{62})\Big)\Big) ,
$$

$$
I^{a,1}_{(b),1} = -\frac{1}{(4\pi)^4}\frac{1}{m_3^2-m_4^2}\sum_{\rho=5}^{7}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{1\rho},x_{3\rho}) - \mathcal{S}L_{i_2}(x_{1\rho},x_{4\rho})\Big) ,
$$

$$
I^{b,1}_{(b),1} = -\frac{1}{(4\pi)^4}\frac{1}{(m_1^2-m_2^2)(m_3^2-m_4^2)(m_5^2-m_6^2)}\Big(m_1^2\Big(\mathcal{S}L_{i_2}(x_{31},x_{51}) - \mathcal{S}L_{i_2}(x_{31},x_{61})
$$

$$
-\mathcal{S}L_{i_2}(x_{41},x_{51}) + \mathcal{S}L_{i_2}(x_{41},x_{61})\Big) - m_2^2\Big(\mathcal{S}L_{i_2}(x_{32},x_{52}) - \mathcal{S}L_{i_2}(x_{32},x_{62})
$$

$$
-\mathcal{S}L_{i_2}(x_{42},x_{52}) + \mathcal{S}L_{i_2}(x_{42},x_{62})\Big)\Big) ,
$$

$$
I^{c,1}_{(b),1} = \frac{1}{(4\pi)^4}\frac{1}{m_1^2-m_2^2}\sum_{\rho=5}^{7}\frac{1}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(m_1^2\mathcal{S}L_{i_2}(x_{31},x_{\rho1}) - m_2^2\mathcal{S}L_{i_2}(x_{32},x_{\rho2})\Big) ,
$$

$$
I_{(b),0} = -\frac{1}{(4\pi)^4}\frac{1}{(m_1^2-m_2^2)(m_3^2-m_4^2)}\sum_{\rho=5}^{7}\frac{1}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(m_1^2\Big(\mathcal{S}L_{i_2}(x_{31},x_{\rho1}) - \mathcal{S}L_{i_2}(x_{41},x_{\rho1})\Big)
$$

$$
-m_2^2\Big(\mathcal{S}L_{i_2}(x_{32},x_{\rho2}) - \mathcal{S}L_{i_2}(x_{42},x_{\rho2})\Big)\Big) . \tag{55}
$$

The reduced formulae for the self energy insertion diagrams (class C) are:

$$
I^a_{(c),2} = I^{a,1}_{(c),2} + (m_4^2+m_5^2)I^a_{(c),1} - m_4^2m_5^2I_{(c),0} ,
$$

$$
I^b_{(c),2} = I^{b,1}_{(c),2} + m_7^2I^b_{(c),1} ,
$$

$$
I^c_{(c),2} = I^{c,1}_{(c),2} + m_6^2I^c_{(c),1} ,
$$

$$
I^d_{(c),2} = I^{d,1}_{(c),2} + m_5^2I^b_{(c),1} + m_7^2I^a_{(c),1} - m_5^2m_7^2I_{(c),0} ,
$$

$$
I^e_{(c),2} = I^{e,1}_{(c),2} + m_5^2I^c_{(c),1} + m_6^2I^a_{(c),1} - m_5^2m_6^2I_{(c),0} ,
$$

$$
I^f_{(c),2} = I^{f,1}_{(c),2} + m_6^2I^c_{(c),1} + m_7^2I^b_{(c),1} - m_6^2m_7^2I_{(c),0} ,
$$

$$
I^a_{(c),1} = I^{a,1}_{(c),1} + m_5^2I_{(c),0} ,
$$

$$
I^b_{(c),1} = I^{b,1}_{(c),1} + m_7^2I_{(c),0} ,
$$

$$
I^c_{(c),1} = I^{c,1}_{(c),1} + m_6^2I_{(c),0} \tag{56}
$$

and

$$I^{a,1}_{(c),2} = \frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}+\Big(3-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu}$$

$$-\ln^2 x_{\rho\mu}-\mathcal{S}L_{i_2}(x_{6\rho},x_{7\rho})\bigg)\ ,$$

$$I^{b,1}_{(c),2} = \frac{1}{(4\pi)^4}\sum_{\rho=1}^{5}\frac{m_\rho^4 m_6^2+m_\rho^2 m_6^4}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho\mu}x_{6\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho\mu}x_{6\mu})$$

$$-\frac{1}{2}\ln^2(x_{\rho\mu}x_{6\mu})\bigg)\ ,$$

$$I^{c,1}_{(c),2} = \frac{1}{(4\pi)^4}\sum_{\rho=1}^{5}\frac{m_\rho^4 m_7^2+m_\rho^2 m_7^4}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho\mu}x_{7\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho\mu}x_{7\mu})$$

$$-\frac{1}{2}\ln^2(x_{\rho\mu}x_{7\mu})\bigg)\ ,$$

$$I^{d,1}_{(c),2} = -\frac{1}{(4\pi)^4}\sum_{\rho=1}^{4}\frac{m_\rho^2 m_6^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho\mu}x_{6\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho\mu}x_{6\mu})$$

$$-\frac{1}{2}\ln^2(x_{\rho\mu}x_{6\mu})\bigg)\ ,$$

$$I^{e,1}_{(c),2} = -\frac{1}{(4\pi)^4}\sum_{\rho=1}^{4}\frac{m_\rho^2 m_7^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho\mu}x_{7\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho\mu}x_{7\mu})$$

$$-\frac{1}{2}\ln^2(x_{\rho\mu}x_{7\mu})\bigg)\ ,$$

$$I^{f,1}_{(c),2} = 0\ ,$$

$$I^{a,1}_{(c),1} = -\frac{1}{(4\pi)^4}\sum_{\rho=1}^{4}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}+\Big(3-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu}$$

$$-\ln^2 x_{\rho\mu}-\mathcal{S}L_{i_2}(x_{6\rho},x_{7\rho})\bigg)\ ,$$

$$I^{b,1}_{(c),1} = \frac{1}{(4\pi)^4}\sum_{\rho=1}^{5}\frac{m_\rho^2 m_6^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho\mu}x_{6\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho\mu}x_{6\mu})$$

$$-\frac{1}{2}\ln^2(x_{\rho\mu}x_{6\mu})\bigg)\ ,$$

$$I^{c,1}_{(c),1} = \frac{1}{(4\pi)^4}\sum_{\rho=1}^{5}\frac{m_\rho^2 m_7^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\bigg(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho\mu}x_{7\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho\mu}x_{7\mu})$$

$$-\frac{1}{2}\ln^2(x_{\rho\mu}x_{7\mu})\Big) ,$$

$$I_{(c),0} = \frac{1}{(4\pi)^4}\sum_{\rho=1}^{5}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}+\Big(3-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu}$$

$$-\ln^2 x_{\rho\mu}-\mathcal{S}L_{i_2}(x_{6\rho},x_{7\rho})\Big) . \tag{57}$$

In a similar way, the formulae for vertex insertion diagrams (class D) are decomposed into

$$\begin{aligned}
I^a_{(d),2} &= I^{a,1}_{(d),2}+(m_3^2+m_4^2)I^a_{(d),1}-m_3^2m_4^2I_{(d),0} ,\\
I^b_{(d),2} &= I^{b,1}_{(d),2}+(m_6^2+m_7^2)I^b_{(d),1}-m_6^2m_7^2I_{(d),0} ,\\
I^c_{(d),2} &= I^{c,1}_{(d),2}+m_5^2I^c_{(d),1} ,\\
I^d_{(d),2} &= I^{d,1}_{(d),2}+m_4^2I^b_{(d),1}+m_7^2I^a_{(d),1}-m_4^2m_7^2I_{(d),0} ,\\
I^e_{(d),2} &= I^{e,1}_{(d),2}+m_4^2I^c_{(d),1}+m_5^2I^a_{(d),1}-m_4^2m_5^2I_{(d),0} ,\\
I^f_{(d),2} &= I^{f,1}_{(d),2}+m_5^2I^b_{(d),1}+m_7^2I^c_{(d),1}-m_5^2m_7^2I_{(d),0} ,\\
I^a_{(d),1} &= I^{a,1}_{(d),1}+m_4^2I_{(d),0} ,\\
I^b_{(d),1} &= I^{b,1}_{(d),1}+m_7^2I_{(d),0} ,\\
I^c_{(d),1} &= I^{c,1}_{(d),1}+m_5^2I_{(d),0}
\end{aligned} \tag{58}$$

with

$$I^{a,1}_{(d),2} = \frac{1}{(4\pi)^4}\frac{1}{(m_1^2-m_2^2)(m_6^2-m_7^2)}\Big(m_1^2\Big(\mathcal{S}L_{i_2}(x_{51},x_{61})-\mathcal{S}L_{i_2}(x_{51},x_{71})\Big)$$

$$-m_2^2\Big(\mathcal{S}L_{i_2}(x_{52},x_{62})-\mathcal{S}L_{i_2}(x_{52},x_{72})\Big)\Big) ,$$

$$I^{b,1}_{(d),2} = -\frac{1}{(4\pi)^4}\sum_{\rho=1}^{4}\frac{m_\rho^2m_5^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{\rho\mu}x_{5\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{\rho\mu}x_{5\mu})$$

$$+\frac{1}{2}\ln^2(x_{\rho\mu}x_{5\mu})\Big) ,$$

$$I^{c,1}_{(d),2} = -\frac{1}{(4\pi)^4}\frac{1}{m_6^2-m_7^2}\sum_{\rho=1}^{4}\frac{1}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(m_\rho^2m_6^2(m_\rho^2+m_6^2)-m_\rho^2m_7^2(m_\rho^2+m_7^2)\Big)\Big(\frac{1}{\varepsilon}-\gamma_E$$

$$+\ln(4\pi)\Big)\ln x_{\rho\mu}+m_\rho^2m_6^2(m_\rho^2+m_6^2)\Big((2-\gamma_E+\ln 4\pi)\ln(x_{\rho\mu}x_{6\mu})-\frac{1}{2}\ln^2(x_{\rho\mu}x_{6\mu})\Big)$$

$$-m_\rho^2 m_7^2(m_\rho^2+m_7^2)\Big((2-\gamma_E+\ln 4\pi)\ln(x_{\rho\mu}x_{7\mu})-\frac{1}{2}\ln^2(x_{\rho\mu}x_{7\mu})\Big)\Big) ,$$

$$I_{(d),2}^{d,1}=\frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}+\Big(3-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu}$$

$$-\ln^2 x_{\rho\mu}-\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})\Big) ,$$

$$I_{(d),2}^{e,1}=\frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}+\Big(2-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu}$$

$$-\frac{m_6^2\ln^2(x_{6\mu}x_{\rho\mu})-m_7^2\ln^2(x_{7\mu}x_{\rho\mu})}{2(m_6^2-m_7^2)}\Big) ,$$

$$I_{(d),2}^{f,1}=-\frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_6^2 m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln(x_{6\mu}x_{\rho\mu})+\Big(2-\gamma_E+\ln 4\pi\Big)\ln(x_{6\mu}x_{\rho\mu})$$

$$+\frac{1}{2}\ln^2(x_{6\mu}x_{\rho\mu})\Big) ,$$

$$I_{(d),1}^{a,1}=-\frac{1}{(4\pi)^4}\frac{1}{m_6^2-m_7^2}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{5\rho},x_{7\rho})\Big) ,$$

$$I_{(d),1}^{b,1}=-\frac{1}{(4\pi)^4}\sum_{\rho=1}^{4}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}+\Big(3-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}\Big) ,$$

$$I_{(d),1}^{c,1}=-\frac{1}{(4\pi)^4}\sum_{\rho=1}^{4}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon}-\gamma_E+\ln(4\pi)\Big)\ln x_{\rho\mu}+\Big(2-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu}$$

$$-\frac{m_6^2\ln^2(x_{6\mu}x_{\rho\mu})-m_7^2\ln^2(x_{7\mu}x_{\rho\mu})}{2(m_6^2-m_7^2)}\Big) ,$$

$$I_{(d),0}=\frac{1}{(4\pi)^4}\frac{1}{m_6^2-m_7^2}\sum_{\rho=1}^{4}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{5\rho},x_{7\rho})\Big) . \tag{59}$$

For the topological class E, the formulae are written as

$$I_{(e),2}^{a}=I_{(e),2}^{a,1}+(m_2^2+m_3^2)I_{(e),1}^{a}-m_2^2m_3^2I_{(e),0} ,$$

$$I_{(e),2}^{b}=I_{(e),2}^{b,1}+(m_6^2+m_7^2)I_{(e),1}^{b}-m_6^2m_7^2I_{(e),0} ,$$

$$I_{(e),2}^{c}=I_{(e),2}^{c,1}+(m_4^2+m_5^2)I_{(e),1}^{c}-m_4^2m_5^2I_{(e),0} ,$$

$$I_{(e),2}^{d}=I_{(e),2}^{d,1}+m_3^2I_{(e),1}^{b}+m_7^2I_{(e),1}^{a}-m_3^2m_7^2I_{(e),0} ,$$

$$
\begin{aligned}
I^e_{(e),2} &= I^{e,1}_{(e),2} + m_3^2 I^c_{(e),1} + m_5^2 I^a_{(e),1} - m_3^2 m_5^2 I_{(e),0} \ , \\
I^f_{(e),2} &= I^{f,1}_{(e),2} + m_5^2 I^c_{(e),1} + m_7^2 I^b_{(e),1} - m_5^2 m_7^2 I_{(e),0} \ , \\
I^a_{(e),1} &= I^{a,1}_{(e),1} + m_3^2 I_{(e),0} \ , \\
I^b_{(e),1} &= I^{b,1}_{(e),1} + m_7^2 I_{(e),0} \ , \\
I^c_{(e),1} &= I^{c,1}_{(e),1} + m_5^2 I_{(e),0}
\end{aligned}
\tag{60}
$$

and

$$
\begin{aligned}
I^{a,1}_{(e),2} &= -\frac{1}{(4\pi)^4}\frac{1}{(m_4^2-m_5^2)(m_6^2-m_7^2)}\Big(m_6^2\Big(\mathcal{S}L_{i_2}(x_{16},x_{46}) - \mathcal{S}L_{i_2}(x_{16},x_{56})\Big) \\
&\quad - m_7^2\Big(\mathcal{S}L_{i_2}(x_{17},x_{47}) - \mathcal{S}L_{i_2}(x_{17},x_{57})\Big)\Big) \ , \\
I^{b,1}_{(e),2} &= \frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon} - \gamma_E + \ln(4\pi)\Big)\ln x_{\rho\mu} + \Big(2-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu} \\
&\quad - \frac{m_4^2\ln^2(x_{4\mu}x_{\rho\mu}) - m_5^2\ln^2(x_{5\mu}x_{\rho\mu})}{2(m_4^2-m_5^2)}\Big) \ , \\
I^{c,1}_{(e),2} &= \frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon} - \gamma_E + \ln(4\pi)\Big)\ln x_{\rho\mu} + \Big(2-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu} \\
&\quad - \frac{m_6^2\ln^2(x_{6\mu}x_{\rho\mu}) - m_7^2\ln^2(x_{7\mu}x_{\rho\mu})}{2(m_6^2-m_7^2)}\Big) \ , \\
I^{d,1}_{(e),2} &= -\frac{1}{(4\pi)^4}\frac{1}{(m_1^2-m_2^2)(m_4^2-m_5^2)}\Big(m_1^2\Big(\mathcal{S}L_{i_2}(x_{41},x_{61}) - \mathcal{S}L_{i_2}(x_{51},x_{61})\Big) \\
&\quad - m_2^2\Big(\mathcal{S}L_{i_2}(x_{42},x_{62}) - \mathcal{S}L_{i_2}(x_{52},x_{62})\Big)\Big) \ , \\
I^{e,1}_{(e),2} &= -\frac{1}{(4\pi)^4}\frac{1}{(m_1^2-m_2^2)(m_6^2-m_7^2)}\Big(m_1^2\Big(\mathcal{S}L_{i_2}(x_{41},x_{61}) - \mathcal{S}L_{i_2}(x_{41},x_{71})\Big) \\
&\quad - m_2^2\Big(\mathcal{S}L_{i_2}(x_{42},x_{62}) - \mathcal{S}L_{i_2}(x_{42},x_{72})\Big)\Big) \ , \\
I^{f,1}_{(e),2} &= \frac{1}{(4\pi)^4}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\Big(\frac{1}{\varepsilon} - \gamma_E + \ln(4\pi)\Big)\ln x_{\rho\mu} + \Big(3-\gamma_E+\ln 4\pi\Big)\ln x_{\rho\mu} \\
&\quad - \ln^2 x_{\rho\mu} - \mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})\Big) \ , \\
I^{a,1}_{(e),1} &= -\frac{1}{(4\pi)^4}\frac{1}{(m_1^2-m_2^2)(m_4^2-m_5^2)(m_6^2-m_7^2)}\Big(m_1^2\Big(\mathcal{S}L_{i_2}(x_{41},x_{61}) - \mathcal{S}L_{i_2}(x_{41},x_{71})
\end{aligned}
$$

$$-\mathcal{S}L_{i_2}(x_{51},x_{61})+\mathcal{S}L_{i_2}(x_{51},x_{71})\Big)-m_2^2\Big(\mathcal{S}L_{i_2}(x_{42},x_{62})-\mathcal{S}L_{i_2}(x_{42},x_{72})$$

$$-\mathcal{S}L_{i_2}(x_{52},x_{62})+\mathcal{S}L_{i_2}(x_{52},x_{72})\Big)\Big)\;,$$

$$I_{(e),1}^{b,1}=-\frac{1}{(4\pi)^4}\frac{1}{(m_4^2-m_5^2)}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})\Big)\;,$$

$$I_{(e),1}^{c,1}=-\frac{1}{(4\pi)^4}\frac{1}{(m_6^2-m_7^2)}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{4\rho},x_{7\rho})\Big)\;,$$

$$I_{(e),0}=-\frac{1}{(4\pi)^4}\frac{1}{(m_4^2-m_5^2)(m_6^2-m_7^2)}\sum_{\rho=1}^{3}\frac{m_\rho^2}{\prod\limits_{\sigma\neq\rho}(m_\sigma^2-m_\rho^2)}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{4\rho},x_{7\rho})$$

$$-\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})+\mathcal{S}L_{i_2}(x_{5\rho},x_{7\rho})\Big)\;. \tag{61}$$

When we compute the amplitude of $\Delta B=2$ processes, the class C and class D contain the ultraviolet divergence and we adopt the $\overline{MS}$- scheme to remove them. After the above step, the functions that appear in the effective Hamiltonian are

$$F_{(a),2}^{a,1}=\sum_{\rho=5}^{7}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(-\mathcal{S}L_{i_2}(x_{1\rho},x_{4\rho})+\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}\Big)\;,$$

$$F_{(a),2}^{b,1}=\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(-\mathcal{S}L_{i_2}(x_{4\rho},x_{5\rho})+\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}\Big)\;,$$

$$F_{(a),2}^{c,1}=-\frac{1}{2}\sum_{\rho_1=1}^{3}\sum_{\rho_2=5}^{7}\frac{x_{\rho_1\mu}^2x_{\rho_2\mu}+x_{\rho_1\mu}x_{\rho_2\mu}^2}{\prod\limits_{\sigma_1\neq\rho_1}(x_{\sigma_1\mu}-x_{\rho_1\mu})\prod\limits_{\sigma_2\neq\rho_2}(x_{\sigma_2\mu}-x_{\rho_2\mu})}\ln^2(x_{\rho_1\mu}x_{\rho_2\mu})\;,$$

$$F_{(a),2}^{d,1}=\frac{1}{x_{5\mu}-x_{6\mu}}\sum_{\rho=1}^{2}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{5\rho})-\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})\Big)\;,$$

$$F_{(a),2}^{e,1}=\frac{1}{2}\sum_{\rho_1=1}^{2}\sum_{\rho_2=5}^{7}\frac{x_{\rho_1\mu}x_{\rho_2\mu}}{\prod\limits_{\sigma_1\neq\rho_1}(x_{\sigma_1\mu}-x_{\rho_1\mu})\prod\limits_{\sigma_2\neq\rho_2}(x_{\sigma_2\mu}-x_{\rho_2\mu})}\ln^2(x_{\rho_1\mu}x_{\rho_2\mu})\;,$$

$$F_{(a),2}^{f,1}=\frac{1}{2}\sum_{\rho_1=1}^{3}\sum_{\rho_2=5}^{6}\frac{x_{\rho_1\mu}x_{\rho_2\mu}}{\prod\limits_{\sigma_1\neq\rho_1}(x_{\sigma_1\mu}-x_{\rho_1\mu})\prod\limits_{\sigma_2\neq\rho_2}(x_{\sigma_2\mu}-x_{\rho_2\mu})}\ln^2(x_{\rho_1\mu}x_{\rho_2\mu})\;,$$

$$F_{(a),1}^{a,1}=-\frac{1}{x_{1\mu}-x_{2\mu}}\sum_{\rho=5}^{7}\frac{1}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(x_{1\mu}\mathcal{S}L_{i_2}(x_{41},x_{\rho1})-x_{2\mu}\mathcal{S}L_{i_2}(x_{42},x_{\rho2})\Big)\;,$$

$$F^{b,1}_{(a),1} = -\frac{1}{x_{5\mu}-x_{6\mu}} \sum_{\rho=1}^{3} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})} \Big(\mathcal{S}L_{i_2}(x_{4\rho}, x_{5\rho}) - \mathcal{S}L_{i_2}(x_{4\rho}, x_{6\rho}) \Big) \ ,$$

$$F^{c,1}_{(a),1} = \frac{1}{2} \sum_{\rho_1=1}^{3} \sum_{\rho_2=5}^{7} \frac{x_{\rho_1\mu}x_{\rho_2\mu}}{\prod\limits_{\sigma_1\neq\rho_1}(x_{\sigma_1\mu}-x_{\rho_1\mu}) \prod\limits_{\sigma_2\neq\rho_2}(x_{\sigma_2\mu}-x_{\rho_2\mu})} \ln^2(x_{\rho_1\mu}x_{\rho_2\mu}) \ ,$$

$$F_{(a),0} = -\sum_{\rho_1=1}^{3} \sum_{\rho_2=5}^{7} \frac{x_{\rho_1\mu}}{\prod\limits_{\sigma_1\neq\rho_1}(x_{\sigma_1\mu}-x_{\rho_1\mu}) \prod\limits_{\sigma_2\neq\rho_2}(x_{\sigma_2\mu}-x_{\rho_2\mu})} \mathcal{S}L_{i_2}(x_{4\rho_1}, x_{\rho_2\rho_1}) \ , \tag{62}$$

and

$$F^{a,1}_{(b),2} = \sum_{\rho=5}^{7} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})} \Big(-\frac{x_{3\mu}}{2(x_{3\mu}-x_{4\mu})} \ln^2(x_{3\mu}x_{\rho\mu}) + \frac{x_{4\mu}}{2(x_{3\mu}-x_{4\mu})} \ln^2(x_{4\mu}x_{\rho\mu}) \Big) \ ,$$

$$F^{b,1}_{(b),2} = -\frac{1}{(x_{1\mu}-x_{2\mu})(x_{3\mu}-x_{4\mu})} \Big(x_{1\mu}\Big(\mathcal{S}L_{i_2}(x_{31}, x_{51}) - \mathcal{S}L_{i_2}(x_{41}, x_{51})\Big)$$
$$-x_{2\mu}\Big(\mathcal{S}L_{i_2}(x_{32}, x_{52}) - \mathcal{S}L_{i_2}(x_{42}, x_{52})\Big)\Big) \ ,$$

$$F^{c,1}_{(b),2} = \sum_{\rho=5}^{7} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})} \Big(-\frac{x_{1\mu}}{2(x_{1\mu}-x_{2\mu})} \ln^2(x_{1\mu}x_{\rho\mu}) + \frac{x_{2\mu}}{2(x_{1\mu}-x_{2\mu})} \ln^2(x_{2\mu}x_{\rho\mu}) \Big) \ ,$$

$$F^{d,1}_{(b),2} = -\frac{1}{(x_{3\mu}-x_{4\mu})(x_{5\mu}-x_{6\mu})} \Big(x_{5\mu}\Big(\mathcal{S}L_{i_2}(x_{15}, x_{35}) - \mathcal{S}L_{i_2}(x_{15}, x_{45})\Big)$$
$$-x_{6\mu}\Big(\mathcal{S}L_{i_2}(x_{16}, x_{36}) - \mathcal{S}L_{i_2}(x_{16}, x_{46})\Big)\Big) \ ,$$

$$F^{e,1}_{(b),2} = \sum_{\rho=5}^{7} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})} \Big(\ln x_{\rho\mu} - \ln^2 x_{\rho\mu} - \mathcal{S}L_{i_2}(x_{1\rho}, x_{3\rho}) \Big) \ ,$$

$$F^{f,1}_{(b),2} = -\frac{1}{(x_{1\mu}-x_{2\mu})(x_{5\mu}-x_{6\mu})} \Big(x_{1\mu}\Big(\mathcal{S}L_{i_2}(x_{31}, x_{51}) - \mathcal{S}L_{i_2}(x_{31}, x_{61})\Big)$$
$$-x_{2\mu}\Big(\mathcal{S}L_{i_2}(x_{32}, x_{52}) - \mathcal{S}L_{i_2}(x_{32}, x_{62})\Big)\Big) \ ,$$

$$F^{a,1}_{(b),1} = -\frac{1}{x_{3\mu}-x_{4\mu}} \sum_{\rho=5}^{7} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})} \Big(\mathcal{S}L_{i_2}(x_{1\rho}, x_{3\rho}) - \mathcal{S}L_{i_2}(x_{1\rho}, x_{4\rho}) \Big) \ ,$$

$$F^{b,1}_{(b),1} = -\frac{1}{(x_{1\mu}-x_{2\mu})(x_{3\mu}-x_{4\mu})(x_{5\mu}-x_{6\mu})} \Big(x_{1\mu}\Big(\mathcal{S}L_{i_2}(x_{31}, x_{51}) - \mathcal{S}L_{i_2}(x_{31}, x_{61})$$
$$-\mathcal{S}L_{i_2}(x_{41}, x_{51}) + \mathcal{S}L_{i_2}(x_{41}, x_{61})\Big) - x_{2\mu}\Big(\mathcal{S}L_{i_2}(x_{32}, x_{52}) - \mathcal{S}L_{i_2}(x_{32}, x_{62})$$
$$-\mathcal{S}L_{i_2}(x_{42}, x_{52}) + \mathcal{S}L_{i_2}(x_{42}, x_{62})\Big)\Big) \ ,$$

$$F^{c,1}_{(b),1} = \frac{1}{x_{1\mu} - x_{2\mu}} \sum_{\rho=5}^{7} \frac{1}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \Big(x_{1\mu} \mathcal{S}L_{i_2}(x_{31}, x_{\rho 1}) - x_{2\mu} \mathcal{S}L_{i_2}(x_{32}, x_{\rho 2}) \Big) \ ,$$

$$F_{(b),0} = -\frac{1}{(x_{1\mu} - x_{2\mu})(x_{3\mu} - x_{4\mu})} \sum_{\rho=5}^{7} \frac{1}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \Big(x_{1\mu} \Big(\mathcal{S}L_{i_2}(x_{31}, x_{\rho 1}) - \mathcal{S}L_{i_2}(x_{41}, x_{\rho 1}) \Big)$$

$$- x_{2\mu} \Big(\mathcal{S}L_{i_2}(x_{32}, x_{\rho 2}) - \mathcal{S}L_{i_2}(x_{42}, x_{\rho 2}) \Big) \Big) \ , \qquad (63)$$

$$F^{a,1}_{(c),2} = \sum_{\rho=1}^{3} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \Big(\ln x_{\rho\mu} - \ln^2 x_{\rho\mu} - \mathcal{S}L_{i_2}(x_{6\rho}, x_{7\rho}) \Big) \ ,$$

$$F^{b,1}_{(c),2} = -\frac{1}{2} \sum_{\rho=1}^{5} \frac{x^2_{\rho\mu} x_{6\mu} + x_{\rho\mu} x^2_{6\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \ln^2(x_{\rho\mu} x_{6\mu}) \ ,$$

$$F^{c,1}_{(c),2} = -\frac{1}{2} \sum_{\rho=1}^{5} \frac{x^2_{\rho\mu} x_{7\mu} + x_{\rho\mu} x^2_{7\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \ln^2(x_{\rho\mu} x_{7\mu}) \ ,$$

$$F^{d,1}_{(c),2} = \frac{1}{2} \sum_{\rho=1}^{4} \frac{x_{\rho\mu} x_{6\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \ln^2(x_{\rho\mu} x_{6\mu}) \ ,$$

$$F^{e,1}_{(c),2} = \frac{1}{2} \sum_{\rho=1}^{4} \frac{x_{\rho\mu} x_{7\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \ln^2(x_{\rho\mu} x_{7\mu}) \ ,$$

$$F^{f,1}_{(c),2} = 0 \ ,$$

$$F^{a,1}_{(c),1} = -\sum_{\rho=1}^{4} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \Big(\ln x_{\rho\mu} - \ln^2 x_{\rho\mu} - \mathcal{S}L_{i_2}(x_{6\rho}, x_{7\rho}) \Big) \ ,$$

$$F^{b,1}_{(c),1} = -\frac{1}{2(4\pi)^4} \sum_{\rho=1}^{5} \frac{x_{\rho\mu} x_{6\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \ln^2(x_{\rho\mu} x_{6\mu}) \ ,$$

$$F^{c,1}_{(c),1} = -\frac{1}{2} \sum_{\rho=1}^{5} \frac{x_{\rho\mu} x_{7\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \ln^2(x_{\rho\mu} x_{7\mu}) \ ,$$

$$F_{(c),0} = \sum_{\rho=1}^{5} \frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho} (x_{\sigma\mu} - x_{\rho\mu})} \Big(\ln x_{\rho\mu} - \ln^2 x_{\rho\mu} - \mathcal{S}L_{i_2}(x_{6\rho}, x_{7\rho}) \Big) \ , \qquad (64)$$

$$F^{a,1}_{(d),2} = \frac{1}{(x_{1\mu} - x_{2\mu})(x_{6\mu} - x_{7\mu})} \Big(x_{1\mu} \Big(\mathcal{S}L_{i_2}(x_{51}, x_{61}) - \mathcal{S}L_{i_2}(x_{51}, x_{71}) \Big)$$

$$- x_{2\mu} \Big(\mathcal{S}L_{i_2}(x_{52}, x_{62}) - \mathcal{S}L_{i_2}(x_{52}, x_{72}) \Big) \Big) \ ,$$

$$F^{b,1}_{(d),2} = -\frac{1}{2(4\pi)^4}\sum_{\rho=1}^{4}\frac{x_{\rho\mu}x_{5\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\ln^2(x_{\rho\mu}x_{5\mu}) ,$$

$$F^{c,1}_{(d),2} = \frac{1}{2}\frac{1}{x_{6\mu}-x_{7\mu}}\sum_{\rho=1}^{4}\frac{1}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(x_{\rho\mu}x_{6\mu}(x_{\rho\mu}+x_{6\mu})\ln^2(x_{\rho\mu}x_{6\mu})$$
$$-x_{\rho\mu}x_{7\mu}(x_{\rho\mu}+x_{7\mu})\ln^2(x_{\rho\mu}x_{7\mu})\Big) ,$$

$$F^{d,1}_{(d),2} = \sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}-\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})\Big) ,$$

$$F^{e,1}_{(d),2} = -\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\frac{x_{6\mu}\ln^2(x_{6\mu}x_{\rho\mu})-x_{7\mu}\ln^2(x_{7\mu}x_{\rho\mu})}{2(x_{6\mu}-x_{7\mu})} ,$$

$$F^{f,1}_{(d),2} = -\frac{1}{2}\sum_{\rho=1}^{3}\frac{x_{6\mu}x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\ln^2(x_{6\mu}x_{\rho\mu}) ,$$

$$F^{a,1}_{(d),1} = -\frac{1}{x_{6\mu}-x_{7\mu}}\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{5\rho},x_{7\rho})\Big) ,$$

$$F^{b,1}_{(d),1} = -\sum_{\rho=1}^{4}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}\Big) ,$$

$$F^{c,1}_{(d),1} = \frac{1}{2}\sum_{\rho=1}^{4}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\frac{x_{6\mu}\ln^2(x_{6\mu}x_{\rho\mu})-x_{7\mu}\ln^2(x_{7\mu}x_{\rho\mu})}{(x_{6\mu}-x_{7\mu})} ,$$

$$F_{(d),0} = \frac{1}{x_{6\mu}-x_{7\mu}}\sum_{\rho=1}^{4}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{5\rho},x_{7\rho})\Big) , \tag{65}$$

$$F^{a,1}_{(e),2} = -\frac{1}{(x_{4\mu}-x_{5\mu})(x_{6\mu}-x_{7\mu})}\Big(x_{6\mu}\Big(\mathcal{S}L_{i_2}(x_{16},x_{46})-\mathcal{S}L_{i_2}(x_{16},x_{56})\Big)$$
$$-x_{7\mu}\Big(\mathcal{S}L_{i_2}(x_{17},x_{47})-\mathcal{S}L_{i_2}(x_{17},x_{57})\Big)\Big) ,$$

$$F^{b,1}_{(e),2} = -\frac{1}{2}\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\frac{x_{4\mu}\ln^2(x_{4\mu}x_{\rho\mu})-x_{5\mu}\ln^2(x_{5\mu}x_{\rho\mu})}{(x_{4\mu}-x_{5\mu})} ,$$

$$F^{c,1}_{(e),2} = -\frac{1}{2}\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\frac{x_{6\mu}\ln^2(x_{6\mu}x_{\rho\mu})-x_{7\mu}\ln^2(x_{7\mu}x_{\rho\mu})}{(x_{6\mu}-x_{7\mu})} ,$$

$$F^{d,1}_{(e),2} = -\frac{1}{(x_{1\mu}-x_{2\mu})(x_{4\mu}-x_{5\mu})}\Big(x_{1\mu}\Big(\mathcal{S}L_{i_2}(x_{41},x_{61})-\mathcal{S}L_{i_2}(x_{51},x_{61})\Big)$$

$$
-x_{2\mu}\Big(\mathcal{S}L_{i_2}(x_{42},x_{62})-\mathcal{S}L_{i_2}(x_{52},x_{62})\Big)\Big)\ ,
$$

$$
F^{e,1}_{(e),2}=-\frac{1}{(x_{1\mu}-x_{2\mu})(x_{6\mu}-x_{7\mu})}\Big(x_{1\mu}\Big(\mathcal{S}L_{i_2}(x_{41},x_{61})-\mathcal{S}L_{i_2}(x_{41},x_{71})\Big)
$$

$$
-x_{2\mu}\Big(\mathcal{S}L_{i_2}(x_{42},x_{62})-\mathcal{S}L_{i_2}(x_{42},x_{72})\Big)\Big)\ ,
$$

$$
F^{f,1}_{(e),2}=\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\ln x_{\rho\mu}-\ln^2 x_{\rho\mu}-\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})\Big)\ ,
$$

$$
F^{a,1}_{(e),1}=-\frac{1}{(x_{1\mu}-x_{2\mu})(x_{4\mu}-x_{5\mu})(x_{6\mu}-x_{7\mu})}\Big(x_{1\mu}\Big(\mathcal{S}L_{i_2}(x_{41},x_{61})-\mathcal{S}L_{i_2}(x_{41},x_{71})
$$

$$
-\mathcal{S}L_{i_2}(x_{51},x_{61})+\mathcal{S}L_{i_2}(x_{51},x_{71})\Big)-x_{2\mu}\Big(\mathcal{S}L_{i_2}(x_{42},x_{62})-\mathcal{S}L_{i_2}(x_{42},x_{72})
$$

$$
-\mathcal{S}L_{i_2}(x_{52},x_{62})+\mathcal{S}L_{i_2}(x_{52},x_{72})\Big)\Big)\ ,
$$

$$
F^{b,1}_{(e),1}=-\frac{1}{(x_{4\mu}-x_{5\mu})}\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})\Big)\ ,
$$

$$
F^{c,1}_{(e),1}=-\frac{1}{(x_{6\mu}-x_{7\mu})}\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{4\rho},x_{7\rho})\Big)\ ,
$$

$$
F_{(e),0}=-\frac{1}{(x_{4\mu}-x_{5\mu})(x_{6\mu}-x_{7\mu})}\sum_{\rho=1}^{3}\frac{x_{\rho\mu}}{\prod\limits_{\sigma\neq\rho}(x_{\sigma\mu}-x_{\rho\mu})}\Big(\mathcal{S}L_{i_2}(x_{4\rho},x_{6\rho})-\mathcal{S}L_{i_2}(x_{4\rho},x_{7\rho})
$$

$$
-\mathcal{S}L_{i_2}(x_{5\rho},x_{6\rho})+\mathcal{S}L_{i_2}(x_{5\rho},x_{7\rho})\Big)\ . \tag{66}
$$

The reduced formulae are similar to $I_{(i)}$, but with replacements of $m_i^2\to x_{i\mu}$, $I_{(i)}\to F_{(i)}$.

C The expressions of $\mathcal{S}L_{i_2}(a,b)$, Æ(a,b), $\mathcal{R}_{i_2}(a)$ and $\Upsilon(a)$

We use the new symbols y_a, y_b to represent the two roots of equation $a(1-x)+bx-x(1-x)=0$, and the functions $\mathcal{S}L_{i_2}(a,b)$ can be written as

$$
\mathcal{S}L_{i_2}(a,b)=14+\frac{(b-1)\ln^2 b}{2(b-a)}+\frac{(a-1)\ln^2 a}{2(a-b)}+\frac{1}{y_a-y_b}\Big(\Big(2y_a+(b-a-1)\Big)L_{i_2}(\frac{1}{1-y_a})
$$

$$
-\Big(2y_b+(b-a-1)\Big)L_{i_2}(\frac{1}{1-y_b})\Big)-\Big(\ln b\ln(1-y_b)-y_a\Big(\ln(a+(b-a)y_a)\ln\frac{y_a-1}{y_a}
$$

$$
+L_{i_2}(\frac{(a-b)y_a}{(a-b)y_a-a})-L_{i_2}(\frac{(a-b)(y_a-1)}{(a-b)y_a-a})\Big)-\Big((2y_a-1)\ln\frac{y_a-1}{y_a}-y_aL_{i_2}(\frac{1}{y_a})
$$

$$
+(y_a-1)L_{i_2}(\frac{1}{1-y_a})-\ln(y_a(y_a-1))\Big)+(y_a\to y_b)\Big). \tag{67}
$$

The expression of $Æ(a,b)$ is

$$Æ(a,b) = \frac{1}{2(b-a)}\Big(b(\ln b+1)^2 - a(\ln a+1)^2\Big) - \frac{2b}{a-b}\ln a - \frac{2a}{b-a}\ln b$$
$$-\frac{a}{b-a}\Big(\ln\frac{b}{a}\ln\frac{a-b}{a} + L_{i_2}(\frac{b}{a})\Big) - \frac{b}{a-b}\Big(\ln\frac{a}{b}\ln\frac{b-a}{b} + L_{i_2}(\frac{a}{b})\Big). \tag{68}$$

It is easy to note that when $a=b$, $Æ(a,b) = 2\ln a + \frac{1}{2}\ln^2 a$. The definition of function $\Upsilon(a)$ is

$$\Upsilon(a) = -\Big(\ln a\ln(1-a) + L_{i_2}(a)\Big) + a\Big(\ln a\ln(1-\frac{1}{a}) - L_{i_2}(\frac{1}{a})\Big). \tag{69}$$

The expression of $\mathcal{R}_{i_2}$ is written as

$$\mathcal{R}_{i_2}(a) = \ln a\ln(1-a) + L_{i_2}(a) - \frac{1}{2}\ln^2 a - \frac{\ln^2 a}{1-a}\ . \tag{70}$$

D The coefficients at Next-to-leading Order

D.1 The gluon corrections

We present here the gluon corrections $L^{\alpha}_{i,j}$ $(\alpha = 1,\cdots,8)$ as follows

$$L^{\alpha}_{i,j} = WW_{\alpha} + 2WH_{\alpha} + HH_{\alpha} + cc_{\alpha} \tag{71}$$

with

$$WW_1 = \frac{1}{3(-1+x_{\rm iw})^3(x_{\rm iw}-x_{j\rm w})^2(-1+x_{j\rm w})^2}\Big(\Big(2x_{\rm iw}(4-27x_{\rm iw}+19x^2_{\rm iw}-5x^4_{\rm iw}+9x^4_{\rm iw})$$
$$-2x_{j\rm w}(4-30x_{\rm iw}-39x^2_{\rm iw}+17x^3_{\rm iw}+39x^4_{\rm iw}+x^5_{\rm iw}) - 2x^2_{j\rm w}(3+79x_{\rm iw}+49x^2_{\rm iw}-91x^3_{\rm iw}-40x^4_{\rm iw})$$
$$+2x^3_{j\rm w}(21+101x_{\rm iw}-37x^2_{\rm iw}-89x^3_{\rm iw}+4x^4_{\rm iw}) - 4x^4_{j\rm w}(15+20x_{\rm iw}-32x^2_{\rm iw}+2x^3_{\rm iw})$$
$$+32x^5_{j\rm w}(1-x_{\rm iw})\Big)(L_{i_2}(\frac{x_{j\rm w}}{x_{\rm iw}}) + \ln\frac{x_{j\rm w}}{x_{\rm iw}}\ln(1-\frac{x_{j\rm w}}{x_{\rm iw}}))$$
$$+\Big(-2x_{\rm iw}(4+3x_{\rm iw}-41x^2_{\rm iw}+65x^3_{\rm iw}-39x^4_{\rm iw}+8x^5_{\rm iw}) + 2x_{j\rm w}(4+30x_{\rm iw}-155x^2_{\rm iw}+265x^3_{\rm iw}$$
$$-221x^4_{\rm iw}+93x^5_{\rm iw}-16x^6_{\rm iw}) - 2x^2_{j\rm w}(27-99x_{\rm iw}+171x^2_{\rm iw}-181x^3_{\rm iw}+110x^4_{\rm iw}-28x^5_{\rm iw})$$
$$+2x^3_{j\rm w}(15-29x_{\rm iw}+x^2_{\rm iw}+25x^3_{\rm iw}-12x^4_{\rm iw})\Big)(L_{i_2}(\frac{x_{\rm iw}}{x_{j\rm w}}) + \ln\frac{x_{\rm iw}}{x_{j\rm w}}\ln(1-\frac{x_{\rm iw}}{x_{j\rm w}}))$$
$$+\Big(4x^2_{\rm iw}(13-53x_{\rm iw}+55x^2_{\rm iw}-19x^3_{\rm iw}+4x^4_{\rm iw}) - 4x_{\rm iw}x_{j\rm w}(20-77x_{\rm iw}+77x^2_{j\rm w}-59x^3_{\rm iw}+47x^4_{\rm iw}-8x^5_{\rm iw})$$
$$+4x^2_{j\rm w}(7-21x_{\rm iw}+29x^2_{\rm iw}-85x^3_{\rm iw}+84x^4_{\rm iw}-14x^5_{\rm iw}) - 4x^3_{j\rm w}(3+7x_{\rm iw}-45x^2_{\rm iw}+41x^3_{\rm iw}$$

$$
\begin{aligned}
&-6x_{i\mathrm{w}}^4)\Big)(L_{i_2}(x_{i\mathrm{w}})+\ln x_{i\mathrm{w}}\ln(1-x_{i\mathrm{w}}))\\
&+\Big(4x_{i\mathrm{w}}^2(3+10x_{i\mathrm{w}}-13x_{i\mathrm{w}}^2)-4x_{i\mathrm{w}}x_{j\mathrm{w}}(12+10x_{i\mathrm{w}}+16x_{i\mathrm{w}}^2-38x_{i\mathrm{w}}^3)+4x_{j\mathrm{w}}^2(9+16x_{i\mathrm{w}}+46x_{i\mathrm{w}}^2\\
&-48x_{i\mathrm{w}}^3-23x_{i\mathrm{w}}^4)-8x_{j\mathrm{w}}^3(8+16x_{i\mathrm{w}}+x_{i\mathrm{w}}^2-26x_{i\mathrm{w}}^3+x_{i\mathrm{w}}^4)+4x_{j\mathrm{w}}^4(15+20x_{i\mathrm{w}}-37x_{i\mathrm{w}}^2+2x_{i\mathrm{w}}^3)\\
&-32x_{j\mathrm{w}}^5(1-x_{i\mathrm{w}})\Big)(L_{i_2}(x_{j\mathrm{w}})+\ln x_{j\mathrm{w}}\ln(1-x_{j\mathrm{w}}))\\
&+\Big(8x_{i\mathrm{w}}(3+x_{i\mathrm{w}}-104x_{i\mathrm{w}}^2+98x_{i\mathrm{w}}^3-46x_{i\mathrm{w}}^4)+8x_{j\mathrm{w}}(3-29x_{i\mathrm{w}}+209x_{i\mathrm{w}}^2-110x_{i\mathrm{w}}^2+25x_{i\mathrm{w}}^4+46x_{i\mathrm{w}}^5)\\
&-8x_{j\mathrm{w}}^2(2+51x_{i\mathrm{w}}+69x_{i\mathrm{w}}^2-86x_{i\mathrm{w}}^3+108x_{i\mathrm{w}}^4)+8x_{j\mathrm{w}}^3(30-41x_{i\mathrm{w}}+3x_{i\mathrm{w}}^2+50x_{i\mathrm{w}}^3+6x_{i\mathrm{w}}^4)\\
&-32x_{j\mathrm{w}}^4(4-13x_{i\mathrm{w}}+9x_{i\mathrm{w}}^2)\Big)+\Big(8x_{i\mathrm{w}}^2(47-80x_{i\mathrm{w}}-42x_{i\mathrm{w}}^2-x_{i\mathrm{w}}^3)+8x_{i\mathrm{w}}x_{j\mathrm{w}}(-47+13x_{i\mathrm{w}}+191x_{i\mathrm{w}}^2\\
&+70x_{i\mathrm{w}}^3+x_{i\mathrm{w}}^4)+8x_{i\mathrm{w}}x_{j\mathrm{w}}^2(105-211x_{i\mathrm{w}}-94x_{i\mathrm{w}}^2-26x_{i\mathrm{w}}^3)-48x_{i\mathrm{w}}x_{j\mathrm{w}}^4(1-x_{i\mathrm{w}})\Big)\ln x_{i\mathrm{w}}\\
&+\Big(x_{i\mathrm{w}}(4+175x_{i\mathrm{w}}+38x_{i\mathrm{w}}^2+57x_{i\mathrm{w}}^3-34x_{i\mathrm{w}}^4)+2x_{j\mathrm{w}}(2-179x_{i\mathrm{w}}-116x_{i\mathrm{w}}^2-69x_{i\mathrm{w}}^3-31x_{i\mathrm{w}}^4+33x_{i\mathrm{w}}^5)\\
&-x_{j\mathrm{w}}^2(5-751x_{i\mathrm{w}}+88x_{i\mathrm{w}}^2-125x_{i\mathrm{w}}^3+31x_{i\mathrm{w}}^4+32x_{i\mathrm{w}}^5)-x_{j\mathrm{w}}^3(13+453x_{i\mathrm{w}}-219x_{i\mathrm{w}}^2+29x_{i\mathrm{w}}^3-36x_{i\mathrm{w}}^4)\\
&+2x_{j\mathrm{w}}^4(15+20x_{i\mathrm{w}}-37x_{i\mathrm{w}}^2+2x_{i\mathrm{w}}^3)-16x_{j\mathrm{w}}^5(1-x_{i\mathrm{w}})\Big)\ln^2 x_{i\mathrm{w}}\\
&+\Big(-16x_{i\mathrm{w}}^2(4-9x_{i\mathrm{w}}+6x_{i\mathrm{w}}^2-x_{i\mathrm{w}}^3)+8x_{i\mathrm{w}}x_{j\mathrm{w}}(13-27x_{i\mathrm{w}}+15x_{i\mathrm{w}}^2-x_{i\mathrm{w}}^3)-8x_{j\mathrm{w}}^2(5+29x_{i\mathrm{w}}\\
&-117x_{i\mathrm{w}}^2+127x_{i\mathrm{w}}^3-44x_{i\mathrm{w}}^4)-96x_{i\mathrm{w}}x_{j\mathrm{w}}^3(1-x_{i\mathrm{w}})^2-48x_{j\mathrm{w}}^4(1-x_{i\mathrm{w}})^2\Big)\ln x_{j\mathrm{w}}\\
&+\Big(-2x_{i\mathrm{w}}(4+15x_{i\mathrm{w}}-41x_{i\mathrm{w}}^2+53x_{i\mathrm{w}}^3-39x_{i\mathrm{w}}^4+8x_{i\mathrm{w}}^5)+2x_{j\mathrm{w}}(-4+110x_{i\mathrm{w}}-189x_{i\mathrm{w}}^2+145x_{i\mathrm{w}}^3\\
&-79x_{i\mathrm{w}}^4+33x_{i\mathrm{w}}^5-16x_{i\mathrm{w}}^6)+2x_{j\mathrm{w}}^2(5-137x_{i\mathrm{w}}+119x_{i\mathrm{w}}^2+101x_{i\mathrm{w}}^3-148x_{i\mathrm{w}}^4+60x_{i\mathrm{w}}^5)\\
&+2x_{j\mathrm{w}}^3(13+123x_{i\mathrm{w}}-237x_{i\mathrm{w}}^2+149x_{i\mathrm{w}}^3-48x_{i\mathrm{w}}^4)-4x_{j\mathrm{w}}^4(15-17x_{i\mathrm{w}}+2x_{i\mathrm{w}}^2)\\
&+32x_{j\mathrm{w}}^5(1-x_{i\mathrm{w}})\Big)\ln x_{i\mathrm{w}}\ln x_{j\mathrm{w}}\\
&+\Big(x_{i\mathrm{w}}(4+3x_{i\mathrm{w}}-41x_{i\mathrm{w}}^2+65x_{i\mathrm{w}}^3-39x_{i\mathrm{w}}^4)+8x_{i\mathrm{w}}^5)+x_{j\mathrm{w}}(4+18x_{i\mathrm{w}}+39x_{i\mathrm{w}}^2-285x_{i\mathrm{w}}^2+377x_{i\mathrm{w}}^3\\
&-169x_{i\mathrm{w}}^4+16x_{i\mathrm{w}}^5)+x_{j\mathrm{w}}^2(-33+12x_{i\mathrm{w}}+230x_{i\mathrm{w}}^2-424x_{i\mathrm{w}}^3+275x_{i\mathrm{w}}^4-60x_{i\mathrm{w}}^5)\\
&+x_{j\mathrm{w}}^3(-10-26x_{i\mathrm{w}}+134x_{i\mathrm{w}}^2-150x_{i\mathrm{w}}^3+52x_{i\mathrm{w}}^4)\Big)\ln^2 x_{j\mathrm{w}}+(x_{i\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)\,, \qquad (72)
\end{aligned}
$$

$$
WH_1=\frac{(\mathcal{Z}_H^{2k})^2}{\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}\Big(\Big(\frac{16}{(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}-\frac{16}{(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})
$$

$$+\ln\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}}\ln(1-\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})\Big)$$

$$+\Big(\frac{32}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}+\frac{32}{3(x_{i\mathrm{w}}-1)^2(x_{j\mathrm{w}}-1)}-\frac{32x_{H_k^-\mathrm{w}}}{3(x_{i\mathrm{w}}-1)^2(x_{j\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-1)}$$

$$+\frac{32x_{H_k^-\mathrm{w}}}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-1)}+\frac{4}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(x_{i\mathrm{w}})+\ln x_{i\mathrm{w}}\ln(1-x_{i\mathrm{w}})\Big)$$

$$-\Big(\frac{16}{(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-1)}+\frac{16}{(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{4}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)$$

$$\Big(L_{i_2}(x_{j\mathrm{w}})+\ln x_{j\mathrm{w}}\ln(1-x_{j\mathrm{w}})\Big)-\frac{16}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}\Big(L_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}})+\ln\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}}\ln(1-\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}})\Big)$$

$$+\frac{32x_{H_k^-\mathrm{w}}^2(1+x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}{3(-1+x_{H_k^-\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big(L_{i_2}(\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}})+\ln\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}}\ln(1-\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}})\Big)$$

$$-\Big(\frac{4x_{H_k^-\mathrm{w}}^2(1+x_{H_k^-\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{4x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{4}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{16}{3(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})+\ln\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}\ln(1-\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})\Big)$$

$$+\Big(\frac{4x_{H_k^-\mathrm{w}}^2(1+x_{H_k^-\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{4x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{4}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})+\ln\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}}\ln(1-\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})\Big)$$

$$+\Big(\frac{4x_{H_k^-\mathrm{w}}(1-x_{H_k^-\mathrm{w}}^2)}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}-\frac{4}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}$$

$$+\frac{16}{3(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(x_{H_k^-\mathrm{w}})+\ln x_{H_k^-\mathrm{w}}\ln(1-x_{H_k^-\mathrm{w}})\Big)$$

$$-\frac{128+32\ln x_{i\mathrm{w}}+30\ln^2 x_{i\mathrm{w}}+4\ln x_{H_k^-\mathrm{w}}\ln x_{i\mathrm{w}}}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{8\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{2\ln^2 x_{H_k^-\mathrm{w}}-16\ln^2 x_{i\mathrm{w}}}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}-\frac{16(\ln^2 x_{H_k^-\mathrm{w}}-\ln x_{i\mathrm{w}}\ln x_{H_k^-\mathrm{w}}+\ln x_{i\mathrm{w}}\ln x_{j\mathrm{w}})}{3(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{8\ln^2\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}}}{3(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-1)}+\frac{4\ln x_{H_k^-\mathrm{w}}\ln x_{j\mathrm{w}}-2\ln^2 x_{j\mathrm{w}}}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-1)}+\frac{32\ln^2 x_{i\mathrm{w}}}{3(x_{i\mathrm{w}}-1)^2(x_{j\mathrm{w}}-1)}$$

$$+\frac{8\ln^2 x_{j\mathrm{w}}}{(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{H_k^-\mathrm{w}})}+\frac{2x_{H_k^-\mathrm{w}}^2(1+x_{H_k^-\mathrm{w}})\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{x_{H_k^-\mathrm{w}}(2x_{H_k^-\mathrm{w}}+1)(x_{H_k^-\mathrm{w}}-1)\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-1)}-\frac{4x_{j\mathrm{w}}\ln^2\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-1)(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$-\frac{2x^2_{H_k^-\mathrm{w}}(1+x_{H_k^-\mathrm{w}})\ln^2\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-1)}-\frac{4(\ln^2 x_{H_k^-\mathrm{w}}-4x_{H_k^-\mathrm{w}}\ln x_{i\mathrm{w}}+4\ln^2 x_{j\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}$$

$$+\frac{32x_{H_k^-\mathrm{w}}(\ln^2 x_{i\mathrm{w}}+3\ln x_{i\mathrm{w}}+4)-4x_{i\mathrm{w}}\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}-16x_{i\mathrm{w}}\ln^2\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{2x_{H_k^-\mathrm{w}}(2\ln x_{H_k^-\mathrm{w}}-\ln(x_{i\mathrm{w}}x_{j\mathrm{w}}))\ln\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{16\ln^2 x_{j\mathrm{w}}}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}$$

$$-\frac{16x^2_{H_k^-\mathrm{w}}\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}+16x_{H_k^-\mathrm{w}}(7\ln x_{H_k^-\mathrm{w}}+2\ln x_{H_k^-\mathrm{w}}\ln x_{j\mathrm{w}}-\ln^2 x_{j\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{16x_{i\mathrm{w}}\ln^2\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}}}{3(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{32x_{H_k^-\mathrm{w}}\ln^2 x_{i\mathrm{w}}}{3(x_{i\mathrm{w}}-1)^2(x_{H_k^-\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}$$

$$+\frac{16x_{i\mathrm{w}}\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{16\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{32x^2_{H_k^-\mathrm{w}}(\ln x_{H_k^-\mathrm{w}}+x_{H_k^-\mathrm{w}}\ln^2 x_{H_k^-\mathrm{w}}+x_{H_k^-\mathrm{w}}\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+(x_{i\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$+(\mathcal{Z}_H^{1k})^2h_bh_d\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\Big(\Big(\frac{8}{3(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}-\frac{8(1-x_{j\mathrm{w}})}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}\Big)$$

$$\Big(L_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})-\ln\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}}\ln(1-\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})\Big)+\frac{8(1-x_{j\mathrm{w}})}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big(L_{i_2}(x_{j\mathrm{w}})+\ln x_{j\mathrm{w}}\ln(1-x_{j\mathrm{w}})\Big)$$

$$+\Big(\frac{8(1-x_{j\mathrm{w}})}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}+\frac{8}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}$$

$$+\frac{8}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})+\ln\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}\ln(1-\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})\Big)$$

$$-\Big(\frac{8(1-x_{j\mathrm{w}})}{3(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}+\frac{8}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}$$

$$+\frac{8}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})+\ln\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}}\ln(1-\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})\Big)$$

$$+\Big(\frac{8(x_{j\mathrm{w}}-1)}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{8}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}\Big)\Big(L_{i_2}(x_{H_k^-\mathrm{w}})+\ln x_{H_k^-\mathrm{w}}\ln(1-x_{H_k^-\mathrm{w}})\Big)$$

$$
+\frac{8x_{i\mathrm{w}}(x_{j\mathrm{w}}-1)\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{8(1-x_{j\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}
$$

$$
-\frac{8x_{j\mathrm{w}}(1-x_{j\mathrm{w}})\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})^2(x_{j\mathrm{w}}-1)(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{8(1-x_{j\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)^2}
$$

$$
+\frac{8x_{i\mathrm{w}}\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{4(1+x_{j\mathrm{w}})\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-1)}
$$

$$
+\frac{8x_{i\mathrm{w}}(x_{j\mathrm{w}}-1)\ln^2\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}-\frac{8x_{i\mathrm{w}}\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}
$$

$$
+\frac{8\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}-\frac{4(x_{j\mathrm{w}}-1)\ln(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})\ln(\frac{x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}}{x_{i\mathrm{w}}^2})}{3x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}
$$

$$
-\frac{4(\ln^2 x_{H_k^-\mathrm{w}}-\ln^2 x_{j\mathrm{w}})}{3(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{8x_{j\mathrm{w}}\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})}{3(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})^2(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{4\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{i\mathrm{w}}-1)(1-x_{j\mathrm{w}})}
$$

$$
-\frac{4\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{8(\ln x_{H_k^-\mathrm{w}}\ln x_{i\mathrm{w}}-\ln x_{H_k^-\mathrm{w}}\ln x_{j\mathrm{w}}-\ln x_{i\mathrm{w}}\ln x_{j\mathrm{w}}+\ln^2 x_{j\mathrm{w}})}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}
$$

$$
+\frac{8x_{i\mathrm{w}}(\ln^2\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}-\frac{4\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})}{3(x_{j\mathrm{w}}-1)(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+(x_{i\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)\,, \tag{73}
$$

$$
WH_2=\frac{1}{2}h_bh_d(\mathcal{Z}_H^{1k})^2\Big(\Big(\frac{x_{j\mathrm{w}}((1+2x_{H_k^-\mathrm{w}})^2+2(x_{i\mathrm{w}}+x_{j\mathrm{w}})(1+x_{H_k^-\mathrm{w}})-8x_{i\mathrm{w}}x_{j\mathrm{w}})}{6(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}-\frac{14}{3(1-x_{i\mathrm{w}})}
$$

$$
+\frac{2}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{2(1+x_{H_k^-\mathrm{w}})}{3(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}-\frac{16(x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})}{3(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}
$$

$$
+\frac{2+x_{H_k^-\mathrm{w}}}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{4x_{i\mathrm{w}}^2-x_{i\mathrm{w}}x_{j\mathrm{w}}}{6(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}+\frac{x_{i\mathrm{w}}(2x_{i\mathrm{w}}-x_{j\mathrm{w}})-x_{j\mathrm{w}}(1+x_{H_k^-\mathrm{w}})^2}{2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}\Big)
$$

$$
\Big(L_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})+\ln\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})\ln(1-\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})\Big)
$$

$$
+\Big(\frac{x_{i\mathrm{w}}(8x_{i\mathrm{w}}x_{j\mathrm{w}}-2(x_{i\mathrm{w}}+x_{j\mathrm{w}})(1+x_{H_k^-\mathrm{w}})-(1+x_{H_k^-\mathrm{w}})^2)}{6(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}-\frac{8(x_{i\mathrm{w}}^2+2x_{i\mathrm{w}}^2x_{j\mathrm{w}}-2x_{H_k^-\mathrm{w}}x_{j\mathrm{w}})}{3(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}
$$

$$
+\frac{x_{i\mathrm{w}}(3(1+x_{H_k^-\mathrm{w}})^2(x_{i\mathrm{w}}-1)+16x_{H_k^-\mathrm{w}})}{6(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}-\frac{8x_{H_k^-\mathrm{w}}(x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}-2x_{i\mathrm{w}}(1+x_{j\mathrm{w}}))}{3(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}
$$

$$
\begin{aligned}
&-\frac{32x_{i\mathrm{w}}x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}}+x_{j\mathrm{w}}}{6(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{1+2x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}}}{6(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}-\frac{14+15x_{H_k^-\mathrm{w}}-96x_{i\mathrm{w}}-31x_{j\mathrm{w}}}{6(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&-\frac{10-32x_{i\mathrm{w}}}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{2+x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}}}{2(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{1}{2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})+\ln\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})\ln(1-\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})\Big)\\
&+\Big(\frac{x_{i\mathrm{w}}((x_{i\mathrm{w}}+x_{j\mathrm{w}})(1+x_{H_k^-\mathrm{w}})-4x_{i\mathrm{w}}x_{j\mathrm{w}}-(1+x_{H_k^-\mathrm{w}})^2)}{6(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{i\mathrm{w}}-2-4x_{H_k^-\mathrm{w}}}{2(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{j\mathrm{w}}-1)}\\
&+\frac{2-x_{H_k^-\mathrm{w}}^2(x_{i\mathrm{w}}-6)-3x_{i\mathrm{w}}-16x_{i\mathrm{w}}^2-x_{H_k^-\mathrm{w}}(97x_{i\mathrm{w}}-33)}{6(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-1)}-\frac{x_{H_k^-\mathrm{w}}}{2(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&+\frac{15+97x_{i\mathrm{w}}-16x_{H_k^-\mathrm{w}}}{6(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-1)}+\frac{32x_{i\mathrm{w}}^2}{3(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-1)^2}+\frac{1}{2(-1+x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(x_{i\mathrm{w}})+\ln x_{i\mathrm{w}}\ln(1-x_{i\mathrm{w}})\Big)\\
&+\Big(\frac{x_{j\mathrm{w}}((x_{i\mathrm{w}}+x_{j\mathrm{w}})(1+x_{H_k^-\mathrm{w}})-4x_{i\mathrm{w}}x_{j\mathrm{w}}-(1+x_{H_k^-\mathrm{w}})^2)}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{3x_{i\mathrm{w}}-5x_{H_k^-\mathrm{w}}-8}{3(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}-\frac{14}{3(x_{i\mathrm{w}}-1)}\\
&+\frac{2+x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}}}{6(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{16(1+x_{H_k^-\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)}\Big)\Big(L_{i_2}(x_{j\mathrm{w}})+\ln x_{j\mathrm{w}}\ln(1-x_{j\mathrm{w}})\Big)\\
&+\Big(\frac{8(x_{H_k^-\mathrm{w}}^2-6x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+x_{i\mathrm{w}}^2)}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\\
&-\frac{16x_{H_k^-\mathrm{w}}(1+x_{i\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}})+\ln(\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}})\ln(1-\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}})\Big)\\
&+\frac{32}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}\Big(L_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}})+\ln(\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}})\ln(1-\frac{x_{j\mathrm{w}}}{x_{H_k^-\mathrm{w}}})\Big)\\
&+\Big(\frac{x_{H_k^-\mathrm{w}}((1+x_{H_k^-\mathrm{w}})^2-(1+x_{H_k^-\mathrm{w}})(x_{i\mathrm{w}}+x_{j\mathrm{w}})+4x_{i\mathrm{w}}x_{j\mathrm{w}})}{6(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\\
&+\frac{2(x_{H_k^-\mathrm{w}}+2x_{H_k^-\mathrm{w}}^2-x_{i\mathrm{w}}+x_{i\mathrm{w}}^2)-9x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}}{6(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{2(1+x_{H_k^-\mathrm{w}})+x_{i\mathrm{w}}}{3(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\\
&+\frac{2(2-x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}{3(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{4}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})+\ln\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}\ln(1-\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})\Big)\\
&+\Big(\frac{x_{H_k^-\mathrm{w}}((1+x_{H_k^-\mathrm{w}})(x_{i\mathrm{w}}+x_{j\mathrm{w}})-(1+x_{H_k^-\mathrm{w}})^2-4x_{i\mathrm{w}}x_{j\mathrm{w}})}{3(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{2(1+2x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&+\frac{2(2-x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}{(x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{4}{3(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})+\ln\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}}\ln(1-\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})\Big)
\end{aligned}
$$

$$+\Big(\frac{x_{H_k^-\mathrm{w}}(x_{H_k^-\mathrm{w}}-1)((1+x_{H_k^-\mathrm{w}})^2-(x_{i\mathrm{w}}+x_{j\mathrm{w}}(1+x_{H_k^-\mathrm{w}})+4x_{i\mathrm{w}}x_{j\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{i\mathrm{w}})(-1+x_{j\mathrm{w}})}$$

$$-\frac{1+x_{H_k^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{i\mathrm{w}})}+\frac{1+x_{H_k^-\mathrm{w}}}{(-1+x_{i\mathrm{w}})(-1+x_{j\mathrm{w}})}\Big)\Big(L_{i_2}(x_{H_k^-\mathrm{w}})+\ln x_{H_k^-\mathrm{w}}\ln(1-x_{H_k^-\mathrm{w}})\Big)$$

$$-\frac{x_{H_k^-\mathrm{w}}^4-x_{i\mathrm{w}}^3+x_{H_k^-\mathrm{w}}^2(x_{j\mathrm{w}}-1)+x_{H_k^-\mathrm{w}}(x_{i\mathrm{w}}-x_{H_k^-\mathrm{w}}^2)(x_{i\mathrm{w}}+x_{j\mathrm{w}}-2))\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})}{6(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{x_{H_k^-\mathrm{w}}(x_{H_k^-\mathrm{w}}^3+2x_{H_k^-\mathrm{w}}^2-2x_{H_k^-\mathrm{w}}-2+x_{i\mathrm{w}}(1-x_{H_k^-\mathrm{w}}-x_{H_k^-\mathrm{w}}^2))\ln^2 x_{H_k^-\mathrm{w}}}{6(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}$$

$$-\frac{x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}(1-x_{H_k^-\mathrm{w}}^2+4x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-x_{H_k^-\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}}}{4(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}$$

$$+\frac{(x_{H_k^-\mathrm{w}}^4-x_{i\mathrm{w}}x_{j\mathrm{w}}^2+(x_{i\mathrm{w}}+x_{j\mathrm{w}}-2)(x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}}^3)+x_{H_k^-\mathrm{w}}^2(4x_{j\mathrm{w}}-1)(x_{i\mathrm{w}}-1))\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})}{6(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}$$

$$+\frac{x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}(x_{i\mathrm{w}}(1+x_{H_k^-\mathrm{w}})^2-3-x_{H_k^-\mathrm{w}}(2+x_{i\mathrm{w}}^2+x_{i\mathrm{w}}x_{j\mathrm{w}}+x_{j\mathrm{w}}(1-x_{i\mathrm{w}})+x_{i\mathrm{w}}^2(4x_{j\mathrm{w}}-1))}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{i\mathrm{w}})(-1+x_{j\mathrm{w}})}$$

$$+\frac{x_{i\mathrm{w}}^2(x_{i\mathrm{w}}+17x_{j\mathrm{w}}+1-94x_{i\mathrm{w}}x_{j\mathrm{w}}-3x_{H_k^-\mathrm{w}}^2(16+5x_{i\mathrm{w}})+x_{H_k^-\mathrm{w}}(17x_{i\mathrm{w}}+17x_{j\mathrm{w}}+62))}{6(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}$$

$$-\frac{4(3x_{H_k^-\mathrm{w}}^2-15x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-2x_{i\mathrm{w}}^2)x_{i\mathrm{w}}\ln x_{i\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}$$

$$+\frac{x_{i\mathrm{w}}^2((28x_{H_k^-\mathrm{w}}-26x_{i\mathrm{w}}-x_{j\mathrm{w}}^2+3x_{j\mathrm{w}}-6)-8x_{H_k^-\mathrm{w}}x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}$$

$$+\frac{4x_{i\mathrm{w}}(1-x_{H_k^-\mathrm{w}})\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+2\Big(\frac{(4x_{H_k^-\mathrm{w}}^2-11x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+x_{i\mathrm{w}}(8x_{i\mathrm{w}}+8x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}}))\ln^2 x_{i\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{2(7x_{H_k^-\mathrm{w}}^2-44x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+7x_{i\mathrm{w}}^2)\ln x_{i\mathrm{w}}-8x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})\ln x_{i\mathrm{w}}\ln x_{j\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{2(9x_{H_k^-\mathrm{w}}^2-63x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+4x_{i\mathrm{w}}^2+4x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})\ln^2 x_{j\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)$$

$$+\frac{x_{i\mathrm{w}}((1+x_{H_k^-\mathrm{w}})(x_{i\mathrm{w}}^2+2x_{j\mathrm{w}}+x_{i\mathrm{w}}x_{j\mathrm{w}})-x_{i\mathrm{w}}(1+x_{H_k^-\mathrm{w}})^2-4x_{i\mathrm{w}}^2x_{j\mathrm{w}})\ln^2(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2(-1+x_{j\mathrm{w}})}$$

$$
\begin{aligned}
&-\frac{\Big((1+x_{H_k^-\mathrm{w}})(x_{i\mathrm{w}}^2(x_{i\mathrm{w}}+x_{j\mathrm{w}}-1-x_{H_k^-\mathrm{w}})-2x_{i\mathrm{w}}x_{j\mathrm{w}})-4x_{i\mathrm{w}}^3x_{j\mathrm{w}}\Big)\ln^2(x_{i\mathrm{w}}x_{j\mathrm{w}})}{12(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2(-1+x_{j\mathrm{w}})}\\
&+\frac{x_{H_k^-\mathrm{w}}((1+2x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}}+2x_{j\mathrm{w}})\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-(1+2x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}}))}{4(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}\\
&+\frac{2x_{H_k^-\mathrm{w}}(\ln^2 x_{H_k^-\mathrm{w}}+4x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}-8x_{i\mathrm{w}}\ln x_{i\mathrm{w}}\ln x_{j\mathrm{w}}-4x_{j\mathrm{w}}\ln^2 x_{j\mathrm{w}}+4x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}\ln^2 x_{j\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&+\frac{2(x_{i\mathrm{w}}+x_{j\mathrm{w}})\ln^2 x_{i\mathrm{w}}+4(x_{H_k^-\mathrm{w}}-1)x_{j\mathrm{w}}\ln x_{H_k^-\mathrm{w}}\ln x_{j\mathrm{w}}+16x_{i\mathrm{w}}x_{j\mathrm{w}}(1+x_{i\mathrm{w}})\ln x_{i\mathrm{w}}\ln x_{j\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}\\
&+\frac{8(4x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})x_{j\mathrm{w}}\ln x_{j\mathrm{w}}+x_{j\mathrm{w}}\ln^2 x_{j\mathrm{w}}(22x_{H_k^-\mathrm{w}}-8x_{i\mathrm{w}}^2+16x_{i\mathrm{w}}-6)-6x_{i\mathrm{w}}\ln x_{i\mathrm{w}}\ln x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}\\
&+\frac{8(x_{i\mathrm{w}}^2\ln^2 x_{i\mathrm{w}}+2(x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}})-6\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}+\frac{2\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)}\\
&+\frac{(x_{i\mathrm{w}}-x_{H_k^-\mathrm{w}}-4)(x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}-x_{j\mathrm{w}}\ln^2 x_{j\mathrm{w}})}{6(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})}+\frac{(1+x_{H_k^-\mathrm{w}})\ln^2 x_{j\mathrm{w}}}{(x_{i\mathrm{w}}-1)(x_{j\mathrm{w}}-1)(x_{j\mathrm{w}}-x_{H_k^-\mathrm{w}})}\\
&-\frac{(1+x_{H_k^-\mathrm{w}})x_{i\mathrm{w}}\ln^2(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})}{(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}(\ln^2 x_{j\mathrm{w}}+\ln^2 x_{i\mathrm{w}}+\ln x_{H_k^-\mathrm{w}}\ln(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}}))}{12(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&-\frac{x_{H_k^-\mathrm{w}}(x_{H_k^-\mathrm{w}}\ln x_{H_k^-\mathrm{w}}\ln(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})+(x_{H_k^-\mathrm{w}}\ln^2 x_{i\mathrm{w}}+x_{i\mathrm{w}}(\ln^2 x_{i\mathrm{w}}-\ln x_{i\mathrm{w}}\ln x_{H_k^-\mathrm{w}})+(x_{i\mathrm{w}}\to x_{j\mathrm{w}})))}{6(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&+\frac{\ln^2 x_{H_k^-\mathrm{w}}}{6(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-1)}+\frac{2(1+x_{H_k^-\mathrm{w}})x_{i\mathrm{w}}\ln^2(\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\\
&-\frac{(1+x_{H_k^-\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})^2}\\
&-\frac{x_{H_k^-\mathrm{w}}^2\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})^2(x_{i\mathrm{w}}-1)}-\frac{x_{i\mathrm{w}}+140x_{H_k^-\mathrm{w}}^2-x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-16-128x_{j\mathrm{w}}}{12(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})^2}\\
&+\frac{4x_{i\mathrm{w}}(6(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})+3(x_{H_k^-\mathrm{w}}-4x_{i\mathrm{w}})\ln x_{i\mathrm{w}}+2(x_{H_k^-\mathrm{w}}-3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}})}{3(x_{i\mathrm{w}}-1)^2(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&+\frac{4x_{i\mathrm{w}}(6(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})+3(x_{H_k^-\mathrm{w}}-4x_{i\mathrm{w}})\ln x_{i\mathrm{w}}+2(x_{H_k^-\mathrm{w}}-3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&-\frac{8(12x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+7x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-1)^2(x_{i\mathrm{w}}-x_{j\mathrm{w}})}-\frac{8(12x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+7x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})}
\end{aligned}
$$

$$-\frac{8x_{H_k^-\mathrm{w}}(\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})+2(x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-2(x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{8x_{H_k^-\mathrm{w}}(2x_{i\mathrm{w}}\ln x_{i\mathrm{w}}\ln x_{H_k^-\mathrm{w}}+3x_{H_k^-\mathrm{w}}\ln x_{H_k^-\mathrm{w}})}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}+\frac{8x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{4x_{i\mathrm{w}}(4x^3_{H_k^-\mathrm{w}}+x^2_{H_k^-\mathrm{w}}(2-4x_{i\mathrm{w}})-5x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+x^2_{i\mathrm{w}})\ln^2(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-8x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{2(6x_{H_k^-\mathrm{w}}-3x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-2x^2_{i\mathrm{w}}+2x^2_{i\mathrm{w}}x_{H_k^-\mathrm{w}}-2x^2_{H_k^-\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{4(x^2_{H_k^-\mathrm{w}}+x_{i\mathrm{w}}(5+x_{j\mathrm{w}})-3x_{H_k^-\mathrm{w}}(1+2x_{i\mathrm{w}}))\ln^2 x_{i\mathrm{w}}}{3(x_{H_k^-\mathrm{w}}-1)(x_{i\mathrm{w}}-1)^2(x_{j\mathrm{w}}-1)}+\frac{(1+x_{H_k^-\mathrm{w}})x_{i\mathrm{w}}\ln^2(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})}{3(x_{i\mathrm{w}}-1)(x_{i\mathrm{w}}-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\Big(3x^2_{j\mathrm{w}}((x_{i\mathrm{w}}+x_{j\mathrm{w}}-2)(x_{H_k^-\mathrm{w}}+1)+1-x^2_{H_k^-\mathrm{w}}-4x_{i\mathrm{w}}x_{j\mathrm{w}})+8x_{i\mathrm{w}}(x^2_{H_k^-\mathrm{w}}-x_{H_k^-\mathrm{w}}(6x_{i\mathrm{w}}+x_{j\mathrm{w}}-4x^2_{j\mathrm{w}})$$

$$+x_{i\mathrm{w}}(x_{i\mathrm{w}}-x_{j\mathrm{w}}(1+4x_{j\mathrm{w}})))\ln^2 x_{i\mathrm{w}}+8(2x^2_{i\mathrm{w}}+15x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-3x^2_{H_k^-\mathrm{w}})x_{j\mathrm{w}}\ln x_{j\mathrm{w}}-16(x^2_{H_k^-\mathrm{w}}+x_{i\mathrm{w}}(x_{i\mathrm{w}}$$

$$+x_{j\mathrm{w}}-4x^2_{j\mathrm{w}})+x_{H_k^-\mathrm{w}}(4x^2_{j\mathrm{w}}+x_{j\mathrm{w}}-6x_{i\mathrm{w}}))\ln x_{i\mathrm{w}}\ln x_{j\mathrm{w}}+2(4x^3_{i\mathrm{w}}+4x^2_{H_k^-\mathrm{w}}(x_{i\mathrm{w}}-2x_{j\mathrm{w}})+(x_{i\mathrm{w}}$$

$$-2-x_{j\mathrm{w}})x^2_{j\mathrm{w}}-4x^2_{i\mathrm{w}}x_{j\mathrm{w}}(3+4x_{j\mathrm{w}})-2x_{H_k^-\mathrm{w}}(12x^2_{i\mathrm{w}}+x^2_{j\mathrm{w}}-2x_{i\mathrm{w}}x_{j\mathrm{w}}(11+4x_{j\mathrm{w}})))\ln^2 x_{j\mathrm{w}}\Big)$$

$$/\Big(3(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-1+x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2\Big)$$

$$+\Big(6x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+12x^2_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+6x^3_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-6x_{H_k^-\mathrm{w}}x^2_{i\mathrm{w}}-6x^2_{H_k^-\mathrm{w}}x^2_{i\mathrm{w}}-12x_{H_k^-\mathrm{w}}x^3_{i\mathrm{w}}+6x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}$$

$$+12x^2_{H_k^-\mathrm{w}}x_{j\mathrm{w}}+6x^3_{H_k^-\mathrm{w}}x_{j\mathrm{w}}-12x_{i\mathrm{w}}x_{j\mathrm{w}}-48x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}-48x^2_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}-12x^3_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}$$

$$+48x_{H_k^-\mathrm{w}}x^2_{i\mathrm{w}}x_{j\mathrm{w}}+18x^2_{H_k^-\mathrm{w}}x^2_{i\mathrm{w}}x_{j\mathrm{w}}+6x^3_{i\mathrm{w}}x_{j\mathrm{w}}+6x_{H_k^-\mathrm{w}}x^3_{i\mathrm{w}}x_{j\mathrm{w}}-6x_{H_k^-\mathrm{w}}x^2_{j\mathrm{w}}-6x^2_{H_k^-\mathrm{w}}x^2_{j\mathrm{w}}$$

$$+18x_{i\mathrm{w}}x^2_{j\mathrm{w}}+18x^2_{i\mathrm{w}}x_{j\mathrm{w}}+48x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x^2_{j\mathrm{w}}+18x^2_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x^2_{j\mathrm{w}}-36x^2_{i\mathrm{w}}x^2_{j\mathrm{w}}-36x_{H_k^-\mathrm{w}}x^2_{i\mathrm{w}}x^2_{j\mathrm{w}}$$

$$-12x_{H_k^-\mathrm{w}}x^3_{j\mathrm{w}}+6x_{i\mathrm{w}}x^3_{j\mathrm{w}}+6x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x^3_{j\mathrm{w}}-(4x^2_{H_k^-\mathrm{w}}+12x_{H_k^-\mathrm{w}}(-1+x_{i\mathrm{w}})$$

$$-x_{i\mathrm{w}}(3+x_{i\mathrm{w}}))(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2(-1+x_{j\mathrm{w}})\ln^2 x_{H_k^-\mathrm{w}}-(x^3_{H_k^-\mathrm{w}}(-3x_{i\mathrm{w}}+x^2_{i\mathrm{w}}+x_{j\mathrm{w}}+2x_{i\mathrm{w}}x_{j\mathrm{w}}-x^2_{j\mathrm{w}})$$

$$-x^2_{H_k^-\mathrm{w}}(2x^3_{i\mathrm{w}}+x^2_{i\mathrm{w}}(1-6x_{j\mathrm{w}})+x_{j\mathrm{w}}(2+x_{j\mathrm{w}}-3x^2_{j\mathrm{w}})+x_{i\mathrm{w}}(2-16x_{j\mathrm{w}}+17x^2_{j\mathrm{w}}))$$

$$+x_{i\mathrm{w}}(x^3_{i\mathrm{w}}(4-5x_{j\mathrm{w}})+x_{i\mathrm{w}}x_{j\mathrm{w}}(-9+14x_{j\mathrm{w}}-9x^2_{j\mathrm{w}})+x^2_{i\mathrm{w}}(-4+5x_{j\mathrm{w}}+4x^2_{j\mathrm{w}})+x_{j\mathrm{w}}(2+3x_{j\mathrm{w}}$$

$$-7x^2_{j\mathrm{w}}+2x^3_{j\mathrm{w}}))+x_{H_k^-\mathrm{w}}(x^4_{i\mathrm{w}}+3x^3_{i\mathrm{w}}(-2+x_{j\mathrm{w}})+x^2_{i\mathrm{w}}(13-22x_{j\mathrm{w}}+7x^2_{j\mathrm{w}})-x_{j\mathrm{w}}(1+3x_{j\mathrm{w}}$$

$$-6x_{j\mathrm{w}}^2+2x_{j\mathrm{w}}^3)+x_{i\mathrm{w}}(-1+4x_{j\mathrm{w}}-6x_{j\mathrm{w}}^2+7x_{j\mathrm{w}}^3)))\ln^2 x_{i\mathrm{w}}+8(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}}-x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}$$
$$+x_{i\mathrm{w}}^2)x_{i\mathrm{w}}^2\ln x_{j\mathrm{w}}+(-2x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}+6x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}x_{j\mathrm{w}}+2x_{i\mathrm{w}}^2x_{j\mathrm{w}}-12x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2x_{j\mathrm{w}}$$
$$-6x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}^2x_{j\mathrm{w}}+6x_{i\mathrm{w}}^3x_{j\mathrm{w}}+14x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}-8x_{i\mathrm{w}}^4x_{j\mathrm{w}}-6x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}^2-6x_{H_k^-\mathrm{w}}^2x_{j\mathrm{w}}^2$$
$$+6x_{i\mathrm{w}}x_{j\mathrm{w}}^2+8x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}^2+6x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}x_{j\mathrm{w}}^2-2x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2-2x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2-4x_{i\mathrm{w}}^3x_{j\mathrm{w}}^2+12x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}^3$$
$$-12x_{i\mathrm{w}}x_{j\mathrm{w}}^3-12x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}^3+12x_{i\mathrm{w}}^2x_{j\mathrm{w}}^3)\ln x_{j\mathrm{w}}+(x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+2x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}-x_{H_k^-\mathrm{w}}^3x_{i\mathrm{w}}$$
$$-x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2-x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}^2+x_{H_k^-\mathrm{w}}^3x_{i\mathrm{w}}^2-x_{i\mathrm{w}}^3-x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}^3+x_{i\mathrm{w}}^4+x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}+2x_{H_k^-\mathrm{w}}^2x_{j\mathrm{w}}$$
$$+3x_{H_k^-\mathrm{w}}^3x_{j\mathrm{w}}-2x_{i\mathrm{w}}x_{j\mathrm{w}}-4x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}-4x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}x_{j\mathrm{w}}-2x_{H_k^-\mathrm{w}}^3x_{i\mathrm{w}}x_{j\mathrm{w}}+3x_{i\mathrm{w}}^2x_{j\mathrm{w}}$$
$$+4x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}^2x_{j\mathrm{w}}-x_{i\mathrm{w}}^4x_{j\mathrm{w}}-9x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}^2-9x_{H_k^-\mathrm{w}}^2x_{j\mathrm{w}}^2-x_{H_k^-\mathrm{w}}^3x_{j\mathrm{w}}^2+8x_{i\mathrm{w}}x_{j\mathrm{w}}^2+16x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}^2$$
$$+6x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}x_{j\mathrm{w}}^2-7x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2-6x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2+2x_{i\mathrm{w}}^3x_{j\mathrm{w}}^2+12x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}^3+x_{H_k^-\mathrm{w}}^2x_{j\mathrm{w}}^3-10x_{i\mathrm{w}}x_{j\mathrm{w}}^3$$
$$-10x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}^3+7x_{i\mathrm{w}}^2x_{j\mathrm{w}}^3)\ln^2 x_{j\mathrm{w}}+2\ln x_{i\mathrm{w}}((7+3x_{H_k^-\mathrm{w}}-10x_{i\mathrm{w}})x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})$$
$$(-1+x_{j\mathrm{w}})+(x_{H_k^-\mathrm{w}}^3(-x_{i\mathrm{w}}+x_{i\mathrm{w}}^2+(-1+x_{j\mathrm{w}})x_{j\mathrm{w}})+x_{i\mathrm{w}}(-(x_{i\mathrm{w}}^2(1-2x_{j\mathrm{w}})^2)+x_{i\mathrm{w}}^3(-1+x_{j\mathrm{w}})$$
$$+2(-1+x_{j\mathrm{w}})^2x_{j\mathrm{w}}(1+x_{j\mathrm{w}})+x_{i\mathrm{w}}x_{j\mathrm{w}}(-7+15x_{j\mathrm{w}}-7x_{j\mathrm{w}}^2))-x_{H_k^-\mathrm{w}}^2(x_{i\mathrm{w}}^2+x_{i\mathrm{w}}^3+x_{j\mathrm{w}}(2-3x_{j\mathrm{w}}$$
$$+x_{j\mathrm{w}}^2)+2x_{i\mathrm{w}}(1-6x_{j\mathrm{w}}+4x_{j\mathrm{w}}^2))-x_{H_k^-\mathrm{w}}(2x_{i\mathrm{w}}^3(-2+x_{j\mathrm{w}})+x_{i\mathrm{w}}^2(-3+18x_{j\mathrm{w}}-14x_{j\mathrm{w}}^2)$$
$$+x_{i\mathrm{w}}(1-12x_{j\mathrm{w}}+18x_{j\mathrm{w}}^2-6x_{j\mathrm{w}}^3)+x_{j\mathrm{w}}(1+x_{j\mathrm{w}}-4x_{j\mathrm{w}}^2+2x_{j\mathrm{w}}^3)))\ln x_{j\mathrm{w}})$$
$$-2(x_{i\mathrm{w}}-x_{j\mathrm{w}})\ln x_{H_k^-\mathrm{w}}((-1+x_{j\mathrm{w}})(-2x_{H_k^-\mathrm{w}}^3+4x_{H_k^-\mathrm{w}}^2(x_{i\mathrm{w}}+x_{j\mathrm{w}})-2x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-4+6x_{i\mathrm{w}}+3x_{j\mathrm{w}})$$
$$+x_{i\mathrm{w}}(3x_{i\mathrm{w}}^2-7x_{j\mathrm{w}}+x_{i\mathrm{w}}(-1+9x_{j\mathrm{w}})))\ln x_{i\mathrm{w}}+(-1+x_{i\mathrm{w}})(-((3x_{H_k^-\mathrm{w}}+4x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}}))$$
$$+2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}^2-3x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}+2x_{j\mathrm{w}}(-2+3x_{j\mathrm{w}}))\ln x_{j\mathrm{w}}))\Big)/\Big(4(-1+x_{i\mathrm{w}})$$
$$(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2(-1+x_{j\mathrm{w}})\Big)+(x_{i\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)\,, \tag{74}$$

$$WH_3=-2WH_2\,, \tag{75}$$

$$HH_1=-\Big(\frac{2}{3\sin^4\beta}x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2F_A^0-\frac{1}{6\sin^4\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(x_{i\mathrm{w}}+x_{j\mathrm{w}})(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(F_A^{1a}+F_A^{1b}$$
$$-F_A^{1c}\Big)+\frac{1}{12\sin^3\beta}(h_d+h_b)x_{i\mathrm{w}}^{\frac{1}{2}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\Big(F_A^{2a}+F_A^{2b}+F_A^{2c}+2F_A^{2d}-2F_A^{2e}$$

$$-2F_A^{2f}\Big)\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_l^-\mathrm{w}}, 0, x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}})$$

$$+\frac{4}{3\sin^4\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(-\sum_{\sigma=u^i,H_k^-,H_l^-}\Big(\frac{x_\sigma\ln^2 x_\sigma}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+(x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)$$

$$-\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})}\Big)$$

$$-\frac{x_{i\mathrm{w}}x_{j\mathrm{w}}}{3\sin^4\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(\sum_{\sigma=u^i,u^j,H_l^-}\Big(-\frac{3x_\sigma\ln^2 x_\sigma}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+2(x_{H_k^-\mathrm{w}}$$

$$+x_{H_l^-\mathrm{w}})\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\frac{x_\sigma(\ln x_\sigma-\ln^2 x_\sigma-\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma}))}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)+2\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})}{-x_{i\mathrm{w}}+x_{j\mathrm{w}}}\Big)$$

$$-\frac{32}{3\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(h_b^2+h_d^2)\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\Big(\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{x_\sigma(\ln x_\sigma-2\ln^2 x_\sigma-\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{2(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{(-1+3\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}\Big)$$

$$-\frac{32}{3\sin^4\beta}x_{i\mathrm{w}}^2x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{x_{H_k^-\mathrm{w}}x_\sigma(-\ln x_\sigma-\ln^2 x_\sigma-\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{2(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{x_{H_k^-\mathrm{w}}(1-3\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\Big(\frac{(x_{H_l^-\mathrm{w}}(\ln x_{H_l^-\mathrm{w}}+\ln^2 x_{H_l^-\mathrm{w}}+\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}})))}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\to x_{j\mathrm{w}})\Big)$$

$$-\Big(\frac{1+3\ln x_{i\mathrm{w}}+ln^2x_{i\mathrm{w}}}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}\Big)\Big)+\frac{16}{3\sin^2\beta}(h_b^2+h_d^2)x_{i\mathrm{w}}x_{j\mathrm{w}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\Big($$

$$\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{x_\sigma(2x_{i\mathrm{w}}\ln x_\sigma-2(x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})\ln^2 x_\sigma-x_{i\mathrm{w}}\ln^2(x_{i\mathrm{w}}x_\sigma)-2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{2(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{(-x_{i\mathrm{w}}+(x_{H_k^-\mathrm{w}}+4x_{i\mathrm{w}})\ln x_{i\mathrm{w}}+(x_{H_k^-\mathrm{w}}+5x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{-x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}+(3x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}})x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}+\frac{-x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}+(3x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}})x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{-x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}+(3x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}})x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\Big(\frac{x_{H_l^-\mathrm{w}}(\ln^2 x_{H_l^-\mathrm{w}}+\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}}))}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$-\frac{2\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}}}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}-\frac{x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}\Big)+\frac{4}{3\sin^4\beta}x_{i\mathrm{w}}^2x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big($$

$$\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{x_\sigma(-(3x_{H_k^-\mathrm{w}}-2x_{i\mathrm{w}})\ln x_\sigma-2(x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(\ln^2 x_\sigma+\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_k^-\mathrm{w}}})))}{2(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{(3x_{H_k^-\mathrm{w}}-2x_{i\mathrm{w}}+(7x_{H_k^-\mathrm{w}}-11x_{i\mathrm{w}})\ln x_{i\mathrm{w}}+2(x_{H_k^-\mathrm{w}}+5x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{x_{i\mathrm{w}}(3x_{H_k^-\mathrm{w}}-2x_{i\mathrm{w}})\ln x_\sigma+2x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{x_{i\mathrm{w}}(3x_{H_k^-\mathrm{w}}-2x_{i\mathrm{w}})\ln x_\sigma+2x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{x_{i\mathrm{w}}(3x_{H_k^-\mathrm{w}}-2x_{i\mathrm{w}})\ln x_\sigma+2x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\Big(\frac{-\frac{3}{2}x_{i\mathrm{w}}\ln x_{i\mathrm{w}}+x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}+x_{H_l^-\mathrm{w}}\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}})}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$+\frac{-3-7\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}}}{2(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}+\frac{3x_{H_l^-\mathrm{w}}\ln x_{H_l^-\mathrm{w}}+2x_{H_l^-\mathrm{w}}\ln^2 x_{H_l^-\mathrm{w}}}{2(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}\Big)$$

$$+\frac{4}{3\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(\sum_{\sigma=u^j,H_k^-,H_l^-}\Big(-\frac{x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}x_\sigma\ln^2(x_\sigma x_{i\mathrm{w}})}{2(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{x_\sigma((-3x_{H_k^-\mathrm{w}}^2+5x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-3x_{i\mathrm{w}}^2)\ln x_\sigma-2(x_{H_k^-\mathrm{w}}^2+x_{i\mathrm{w}}^2)(\ln^2 x_\sigma+\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma})))}{2(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)$$

$$+\frac{3x^2_{H^-_k\mathrm{w}}-5x_{H^-_k\mathrm{w}}x_{i\mathrm{w}}+3x^2_{i\mathrm{w}}+(7x^2_{H^-_k\mathrm{w}}-2x_{H^-_k\mathrm{w}}x_{i\mathrm{w}}+7x^2_{i\mathrm{w}})\ln x_{i\mathrm{w}}}{2(x_{H^-_k\mathrm{w}}-x_{i\mathrm{w}})(x_{H^-_l\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{(x^2_{H^-_k\mathrm{w}}+4x_{H^-_k\mathrm{w}}x_{i\mathrm{w}}+x^2_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H^-_k\mathrm{w}}-x_{i\mathrm{w}})(x_{H^-_l\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{(3x^2_{H^-_k\mathrm{w}}x_{i\mathrm{w}}-5x_{H^-_k\mathrm{w}}x^2_{i\mathrm{w}}+3x^3_{i\mathrm{w}})\ln x_{i\mathrm{w}}+2(x^2_{H^-_k\mathrm{w}}x_{i\mathrm{w}}+x^3_{i\mathrm{w}}+x_{H^-_k\mathrm{w}}x^2_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H^-_k\mathrm{w}}-x_{i\mathrm{w}})(x_{H^-_l\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{(3x^2_{H^-_k\mathrm{w}}x_{i\mathrm{w}}-5x_{H^-_k\mathrm{w}}x^2_{i\mathrm{w}}+3x^3_{i\mathrm{w}})\ln x_{i\mathrm{w}}+2(x^2_{H^-_k\mathrm{w}}x_{i\mathrm{w}}+x^3_{i\mathrm{w}}+x_{H^-_k\mathrm{w}}x^2_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H^-_k\mathrm{w}}-x_{i\mathrm{w}})(x_{H^-_l\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{(3x^2_{H^-_k\mathrm{w}}x_{i\mathrm{w}}-5x_{H^-_k\mathrm{w}}x^2_{i\mathrm{w}}+3x^3_{i\mathrm{w}})\ln x_{i\mathrm{w}}+2(x^2_{H^-_k\mathrm{w}}x_{i\mathrm{w}}+x^3_{i\mathrm{w}}+x_{H^-_k\mathrm{w}}x^2_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H^-_k\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H^-_l\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\Big(\frac{(3x_{H^-_k\mathrm{w}}-5x_{i\mathrm{w}})x_{H^-_l\mathrm{w}}\ln x_{H^-_l\mathrm{w}}+2(x_{H^-_k\mathrm{w}}+x_{H^-_l\mathrm{w}})x_{H^-_l\mathrm{w}}\ln^2 x_{H^-_l\mathrm{w}}-x_{H^-_l\mathrm{w}}x_{i\mathrm{w}}\ln^2(x_{H^-_l\mathrm{w}}x_{i\mathrm{w}})}{2(-x_{H^-_l\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H^-_l\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{x_{H^-_l\mathrm{w}}(x_{H^-_k\mathrm{w}}+x_{H^-_l\mathrm{w}})\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H^-_l\mathrm{w}}})}{(-x_{H^-_l\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H^-_l\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H^-_l\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$+\frac{-(x_{H^-_k\mathrm{w}}+x_{H^-_l\mathrm{w}})(3+7\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})+x_{i\mathrm{w}}(5+9\ln x_{i\mathrm{w}}+4\ln^2 x_{i\mathrm{w}})}{2(-x_{H^-_l\mathrm{w}}+x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{(x_{H^-_k\mathrm{w}}+x_{H^-_l\mathrm{w}})x_{i\mathrm{w}}(-3\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})+x^2_{i\mathrm{w}}(5\ln x_{i\mathrm{w}}+4\ln^2 x_{i\mathrm{w}})}{2(-x_{H^-_l\mathrm{w}}+x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})^2}$$

$$+\frac{(x_{H^-_k\mathrm{w}}+x_{H^-_l\mathrm{w}})x_{i\mathrm{w}}(-3\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})+x^2_{i\mathrm{w}}(5\ln x_{i\mathrm{w}}+4\ln^2 x_{i\mathrm{w}})}{2(-x_{H^-_l\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{3+7\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}}}{2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{\Big(x_{i\mathrm{w}}(3\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})+(x_{i\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)-2x_{j\mathrm{w}}\Upsilon(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})}{2(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{3x^2_{H^-_l\mathrm{w}}\ln x_{H^-_l\mathrm{w}}}{2(-x_{H^-_l\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H^-_l\mathrm{w}}+x_{j\mathrm{w}})}+\frac{3x_{H^-_l\mathrm{w}}x_{j\mathrm{w}}\ln x_{j\mathrm{w}}}{2(-x_{j\mathrm{w}}+x_{i\mathrm{w}})^2(x_{H^-_l\mathrm{w}}-x_{j\mathrm{w}})}\Big)$$

$$+\frac{8}{3\sin^4\beta}x^2_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}^{2k}_H)^2(\mathcal{Z}^{2l}_H)^2\Big(-\sum_{\sigma=u^i,u^j,H^-_l}\frac{x_\sigma\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$\sum_{\sigma=u^i,u^j,H^-_k,H^-_l}\frac{x_\sigma(-2\ln x_\sigma+\ln^2 x_\sigma+2(x_{H^-_k\mathrm{w}}-x_{i\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})+2\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$
+\frac{x_{H_l^-\mathrm{w}}(5\ln x_{H_l^-\mathrm{w}}+\ln^2 x_{H_l^-\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{j\mathrm{w}}-x_{H_l^-\mathrm{w}})}-\frac{x_{H_l^-\mathrm{w}}(5\ln x_{H_l^-\mathrm{w}}+\ln^2 x_{H_l^-\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})^2}\Big)
$$

$$
-\frac{16}{3\sin^4\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(
$$

$$
\sum_{\sigma=u^i,u^j,H_l^-}\frac{x_\sigma(3\ln x_\sigma+3\ln^2 x_\sigma-2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}}+x_\sigma)\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})+2\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\sum_{\sigma=u^i,u^j,H_k^-,H_l^-}\frac{x_{H_k^-\mathrm{w}}x_\sigma(-6\ln x_\sigma-3\ln^2 x_\sigma+2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})-2\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}(-\ln x_{H_l^-\mathrm{w}}+\ln^2 x_{H_l^-\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{j\mathrm{w}}-x_{H_l^-\mathrm{w}})}-\frac{x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}(4\ln x_{H_l^-\mathrm{w}}+\ln^2 x_{H_l^-\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})^2}\Big)
$$

$$
+\frac{1}{3\sin^4\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}^2(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(-\sum_{\sigma=u^i,u^j,H_l^-}\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma}))+x_\sigma(\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{j\mathrm{w}}}{x_\sigma}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)
$$

$$
+\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)
$$

$$
-\frac{1}{3\sin^4\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(\sum_{\sigma=u^i,u^j,H_l^-}\Big(-\frac{x_\sigma(x_{H_k^-\mathrm{w}}\ln^2(x_{H_k^-\mathrm{w}}x_\sigma)-x_{j\mathrm{w}}\ln(x_{j\mathrm{w}}x_\sigma))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
-\frac{x_\sigma\ln^2 x_\sigma-2(x_{j\mathrm{w}}+x_{H_k^-\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-4x_\sigma\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{(2x_{j\mathrm{w}}^2-6x_{H_l^-\mathrm{w}}^2)(\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma}))+8x_{H_l^-\mathrm{w}}x_\sigma(\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{j\mathrm{w}}}{x_\sigma}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
-\frac{6(x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})(\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}
$$

$$
-\frac{8(x_{i\mathrm{w}}\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-x_{j\mathrm{w}}\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+6\frac{\text{Æ}(x_{i\mathrm{w}},x_{H_k^-\mathrm{w}})-\text{Æ}(x_{i\mathrm{w}},x_{j\mathrm{w}})}{x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}}}\Big)
$$

$$
+\frac{4}{3\sin^4\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\bigg(\frac{\AE(x_{i\mathrm{w}},x_{H_k^-\mathrm{w}})-\AE(x_{i\mathrm{w}},x_{j\mathrm{w}})}{x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}}}-\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})}{x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}}}
$$

$$
-\frac{(x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{H_l^-\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})+\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}}))}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}
$$

$$
+\frac{(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})(-\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_{H_l^-\mathrm{w}}})+\Upsilon(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})+(x_{H_l^-\mathrm{w}}\to x_{i\mathrm{w}}))}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\bigg)+(x_{i\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\,, \tag{76}
$$

$$
HH_2=-\frac{1}{12\sin^2\beta}h_bh_d\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\bigg((x_{i\mathrm{w}}^2x_{j\mathrm{w}}+x_{i\mathrm{w}}x_{j\mathrm{w}}^2)F_A^0+(x_{i\mathrm{w}}+x_{j\mathrm{w}})^2\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)
$$

$$
+(x_{i\mathrm{w}}+x_{j\mathrm{w}})F_A^{2d}\bigg)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_l^-\mathrm{w}},0,x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}})
$$

$$
+\frac{1}{3\sin^2\beta}(x_{i\mathrm{w}}+x_{j\mathrm{w}})h_bh_d\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\bigg[-\sum_{\sigma=u^i,u^j,H_l^-}\frac{x_{H_l^-\mathrm{w}}\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}-\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})}{-x_{i\mathrm{w}}+x_{j\mathrm{w}}}
$$

$$
+2\bigg(\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})}+\sum_{\sigma=u^i,H_k^-,H_l^-}\Big(\frac{x_\sigma\ln^2x_\sigma}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+(x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)\bigg)
$$

$$
+\sum_{\sigma=u^j,H_k^-,H_l^-}\Big(-\frac{x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}\ln^2(x_{H_l^-\mathrm{w}}x_\sigma)}{(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{x_\sigma((x_{H_l^-\mathrm{w}}^2+x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}+x_{i\mathrm{w}}^2)\ln x_\sigma-2(x_{H_l^-\mathrm{w}}^2+x_{i\mathrm{w}}^2)(\ln^2x_\sigma+\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma})))}{(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)
$$

$$
+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-1+2\ln x_{i\mathrm{w}}+8\ln^2x_{i\mathrm{w}})+(x_{H_k^-\mathrm{w}}^2+x_{i\mathrm{w}}^2)(-1+3\ln x_{i\mathrm{w}}+2\ln^2x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}
$$

$$
+\frac{(x_{H_k^-\mathrm{w}}^2+x_{i\mathrm{w}}^2)x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2x_{i\mathrm{w}})+3x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2\ln^2x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}
$$

$$
+\frac{(x_{H_k^-\mathrm{w}}^2+x_{i\mathrm{w}}^2)x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2x_{i\mathrm{w}})+3x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2\ln^2x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}
$$

$$
+\frac{(x_{H_k^-\mathrm{w}}^2+x_{i\mathrm{w}}^2)x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2x_{i\mathrm{w}})+3x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2\ln^2x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}
$$

$$
+\frac{(x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(1-3\ln x_{i\mathrm{w}}-2\ln^2x_{i\mathrm{w}})+x_{i\mathrm{w}}(10\ln x_{i\mathrm{w}}+4\ln^2x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}
$$

$$+\Big(\frac{(x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})x_{H_l^-\mathrm{w}}(-\ln x_{H_l^-\mathrm{w}}+2\ln^2 x_{H_l^-\mathrm{w}}+2\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}}))}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{H_l^-\mathrm{w}})}$$

$$+\frac{x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}(\ln x_{H_l^-\mathrm{w}}+\ln^2(x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}))}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{H_l^-\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$+\frac{x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})+3x_{i\mathrm{w}}^2\ln^2 x_{i\mathrm{w}}}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{H_l^-\mathrm{w}})}$$

$$+\frac{x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})+3x_{i\mathrm{w}}^2\ln^2 x_{i\mathrm{w}}}{(-x_{j\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{j\mathrm{w}}+x_{H_l^-\mathrm{w}})}$$

$$+\frac{-1+3\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}}}{2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{-x_{i\mathrm{w}}\ln x_{i\mathrm{w}}+2x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}+x_{j\mathrm{w}}(\ln x_{j\mathrm{w}}-2\ln^2 x_{j\mathrm{w}})}{(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{21(\text{Æ}(x_{i\mathrm{w}},x_{H_k^-\mathrm{w}})-\text{Æ}(x_{i\mathrm{w}},x_{j\mathrm{w}}))}{16(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-4\Big(\sum_{\sigma=u^i,u^j,H_k^-,H_l^-}\frac{x_{H_k^-\mathrm{w}}x_\sigma(2\ln x_\sigma-3\ln^2 x_\sigma+2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})+\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$-\sum_{\sigma=u^i,u^j,H_l^-}\frac{x_\sigma(2\ln x_\sigma-3\ln^2 x_\sigma+2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})+\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$-\frac{2\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_{j\mathrm{w}}})}{x_{i\mathrm{w}}-x_{j\mathrm{w}}}+\frac{x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}(x_{i\mathrm{w}}-x_{j\mathrm{w}})\ln^2 x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}})^2(x_{j\mathrm{w}}-x_{H_l^-\mathrm{w}})}\Big)$$

$$-\frac{x_{H_l^-\mathrm{w}}(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})}{x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}}}\sum_{\sigma=u^i,u^j,H_l^-}\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\frac{x_{i\mathrm{w}}\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-x_{j\mathrm{w}}\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{x_{H_l^-\mathrm{w}}}{x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}}}\sum_{\sigma=u^i,u^j,H_l^-}\frac{x_\sigma(\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{j\mathrm{w}}}{x_\sigma}))}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}-\frac{x_{H_l^-\mathrm{w}}(\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})^2(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{5}{16}\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})}{x_{i\mathrm{w}}-x_{H_l^-\mathrm{w}}}-\frac{(-\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_{H_l^-\mathrm{w}}})+\Upsilon(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})+(x_{H_l^-\mathrm{w}}\to x_{i\mathrm{w}}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{(x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{H_l^-\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})+\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}}))}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big]$$

$$-\frac{x_{i\mathrm{w}}(x_{i\mathrm{w}}+x_{j\mathrm{w}})}{3\sin^2\beta}h_bh_d\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\Big[$$

$$-2\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{(3x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})x_\sigma(\ln x_\sigma-\ln^2 x_\sigma-\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))+x_{H_k^-\mathrm{w}}\ln x_\sigma+x_{i\mathrm{w}}\ln^2(x_{H_k^-\mathrm{w}}x_{i\mathrm{w}})}{(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{2(5x_{i\mathrm{w}}-3x_{H_k^-\mathrm{w}})(-1+\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}})+x_{H_k^-\mathrm{w}}(1+\ln x_{i\mathrm{w}})+x_{i\mathrm{w}}(8-\ln x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{6x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(\ln x_{i\mathrm{w}}-\ln^2 x_{i\mathrm{w}})+x_{i\mathrm{w}}(4x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}})\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{6x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(\ln x_{i\mathrm{w}}-\ln^2 x_{i\mathrm{w}})+x_{i\mathrm{w}}(4x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}})\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{6x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(\ln x_{i\mathrm{w}}-\ln^2 x_{i\mathrm{w}})+x_{i\mathrm{w}}(4x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}})\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\Big(\frac{16x_{H_l^-\mathrm{w}}\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}})+x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})-x_{H_l^-\mathrm{w}}(13\ln x_{H_l^-\mathrm{w}}-14\ln^2 x_{H_l^-\mathrm{w}})}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$+16\Big(\frac{-1-\ln x_{i\mathrm{w}}-ln^2x_{i\mathrm{w}}}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}-\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}+\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}-\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$-\frac{1-3\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}}}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})}\Big)\Big)-2\Big(\sum_{\sigma=u^i,u^j,H_l^-}\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$-\frac{(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma}))+x_\sigma(\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{j\mathrm{w}}}{x_\sigma}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)$$

$$-\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)+\frac{2x_{H_l^-\mathrm{w}}(\ln x_{H_l^-\mathrm{w}}+\ln^2 x_{H_l^-\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2}$$

$$+2\sum_{\sigma=u^i,u^j,H_k^-,H_l^-}\frac{x_\sigma(-2\ln x_\sigma+\ln^2 x_\sigma+2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})+2\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big]$$

$$-\frac{1}{3\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}h_bh_d((\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{2l})^2+(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{1l})^2)\Big[$$

$$-8\Big(\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{x_{H_k^-\mathrm{w}}x_\sigma(\ln x_\sigma-2\ln^2 x_\sigma-2\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\Big(\frac{-x_{H_l^-\mathrm{w}}\ln x_{H_l^-\mathrm{w}}+\ln^2 x_{H_l^-\mathrm{w}}+2\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}})}{2(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$
+\frac{x_{H_k^-\mathrm{w}}(-1+3\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}
$$

$$
+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}
$$

$$
-\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}-\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}-\frac{1-3\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}\Big)
$$

$$
+\sum_{\sigma=u^i,u^j,H_l^-}\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\frac{(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma}))+x_\sigma(\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{j\mathrm{w}}}{x_\sigma}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)
$$

$$
-\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)-16\sum_{\sigma=u^i,H_k^-,H_l^-}\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+48\sum_{\sigma=u^i,u^j,H_l^-}\frac{x_\sigma\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
-8\Big(\sum_{\sigma=u^i,u^j,H_k^-,H_l^-}\frac{13x_\sigma\ln^2 x_\sigma-2x_\sigma\ln x_\sigma-6x_\sigma(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})+10x_\sigma\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{x_{H_l^-\mathrm{w}}(2\ln x_{H_l^-\mathrm{w}}+3\ln^2 x_{H_l^-\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}-\frac{x_{H_l^-\mathrm{w}}(2\ln x_{H_l^-\mathrm{w}}+3\ln^2 x_{H_l^-\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2}\Big)
$$

$$
-16\Big(\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{x_\sigma(2x_{i\mathrm{w}}\ln x_\sigma-2(x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(\ln^2 x_\sigma+\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))-x_{i\mathrm{w}}\ln^2(x_{i\mathrm{w}}x_{j\mathrm{w}}))}{2(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{-x_{i\mathrm{w}}+(2x_{H_k^-\mathrm{w}}+4x_{i\mathrm{w}})\ln x_{i\mathrm{w}}+(x_{H_k^-\mathrm{w}}+5x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}+x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}
$$

$$
+\frac{x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}+x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}+x_{i\mathrm{w}}(x_{H_k^-\mathrm{w}}+3x_{i\mathrm{w}})\ln^2 x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}
$$

$$
+\Big(\frac{x_{H_l^-\mathrm{w}}(ln^2 x_{H_l^-\mathrm{w}}+\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}}))}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)-\frac{2\ln x_{i\mathrm{w}}+\ln^2 x_{i\mathrm{w}}}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}
$$

$$
-\frac{x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})^2}-\frac{x_{i\mathrm{w}}\ln^2 x_{i\mathrm{w}}}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}\Big)\Big]\,, \tag{77}
$$

$$
HH_3=-2HH_2\,, \tag{78}
$$

$$
HH_4=\frac{h_b^2+h_d^2}{\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\Big[\Big(-F_A^{1a}-F_A^{1b}+\frac{13}{32}F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_l^-\mathrm{w}},0,x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}})
$$

$$
-\frac{4}{3}\Big(-\sum_{\sigma=u^j,H_k^-,H_l^-}\frac{x_{H_k^-\mathrm{w}}x_\sigma(\ln x_\sigma-2\ln^2 x_\sigma-2\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma}))}{(x_{i\mathrm{w}}-x_\sigma)^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$+\Big(\frac{-x_{H_l^-\mathrm{w}}\ln x_{H_l^-\mathrm{w}})+\ln^2 x_{H_l^-\mathrm{w}}+2\Upsilon(\frac{x_{i\mathrm{w}}}{x_{H_l^-\mathrm{w}}})}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}+(x_{H_l^-\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big)$$

$$+\frac{x_{H_k^-\mathrm{w}}(3\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}$$

$$+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}(-\ln x_{i\mathrm{w}}+2\ln^2 x_{i\mathrm{w}})}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$

$$+\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})^2}+\frac{x_{i\mathrm{w}}(\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{j\mathrm{w}}-x_{i\mathrm{w}})}+\frac{1-3\ln x_{i\mathrm{w}}-2\ln^2 x_{i\mathrm{w}})}{(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}\Big)$$

$$-\frac{4}{3}\Big(-\sum_{\sigma=u^i,u^j,H_l^-}\frac{3x_\sigma\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\frac{x_{H_l^-\mathrm{w}}(2\ln x_{H_l^-\mathrm{w}}+3\ln^2 x_{H_l^-\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\sum_{\sigma=u^i,u^j,H_k^-,H_l^-}\frac{x_\sigma\ln x_\sigma-13x_\sigma\ln^2 x_\sigma+6x_\sigma(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})\mathcal{R}_{i_2}(\frac{x_{i\mathrm{w}}}{x_\sigma})-10x_\sigma\Upsilon(\frac{x_{i\mathrm{w}}}{x_\sigma})}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$-\frac{x_{H_l^-\mathrm{w}}(2\ln x_{H_l^-\mathrm{w}}+3\ln^2 x_{H_l^-\mathrm{w}})}{2(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2}\Big)+\frac{7}{6}\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{j\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\sum_{\sigma=u^i,u^j,H_l^-}\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\frac{(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_\sigma}))+x_\sigma(\Upsilon(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{j\mathrm{w}}}{x_\sigma}))}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)\Big)$$

$$-\frac{1}{2}\frac{\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{H_l^-\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_{i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{j\mathrm{w}}}{x_{H_l^-\mathrm{w}}})}{(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{1}{4}\sum_{\sigma=u^i,u^j,H_l^-}\frac{\mathcal{R}_{i_2}(\frac{x_{H_k^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+(x_{i\mathrm{w}}\leftrightarrow x_{j\mathrm{w}})\Big]\;, \tag{79}$$

$$HH_5=\frac{1}{4}HH_4\;, \tag{80}$$

$$cc_1=\frac{1}{6}a_+^{(c)}b_-^{(c)}c_+^{(c)}d_-^{(c)}\Big(F_A^{2a}+F_A^{2b}+\frac{1}{2}F_A^{2c}+2F_A^{2d}-3F_A^{2e}-F_A^{2f}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde U_\beta^j\mathrm{w}},0,x_{\kappa_\eta^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde U_\beta^j\mathrm{w}})$$

$$+\frac{4}{3}a_+^{(c)}b_-^{(c)}c_+^{(c)}d_-^{(c)}\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\tilde U_\alpha^i\mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\tilde U_\beta^j\mathrm{w}}})}{x_{\tilde U_\alpha^i\mathrm{w}}-x_{\tilde U_\beta^j\mathrm{w}}}-\Big(x_{\kappa_\eta^-\mathrm{w}}-x_{\kappa_\lambda^-\mathrm{w}}\Big)\sum_{\sigma=\tilde U_\alpha^i,\tilde U_\beta^j,\kappa_\eta^-}\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)$$

$$+\frac{1}{3}a_+^{(c)}b_-^{(c)}c_+^{(c)}d_-^{(c)}\Big(-\sum_{\sigma=\tilde U_\alpha^i,\tilde U_\beta^i,\kappa_\eta^-}\frac{x_\sigma(x_{\kappa_\lambda^-\mathrm{w}}\ln^2(x_\sigma x_{\kappa_\lambda^-\mathrm{w}})-x_{\tilde U_\beta^j\mathrm{w}}\ln^2(x_\sigma x_{\tilde U_\beta^j\mathrm{w}}))}{2(x_{\kappa_\lambda^-\mathrm{w}}-x_{\tilde U_\beta^j\mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{x_{\tilde{U}^j_\beta \mathrm{w}}^2+2x_{\kappa^-_\lambda \mathrm{w}}x_{\tilde{U}^j_\beta \mathrm{w}}-2x_{\kappa^-_\lambda \mathrm{w}}^2}{x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}}}\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})-\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+(x_{\tilde{U}^j_\beta \mathrm{w}}+2x_{\kappa^-_\eta \mathrm{w}})\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+2\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\eta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\eta \mathrm{w}}}{x_{\tilde{U}^j_\beta \mathrm{w}}})}{x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}}}$$

$$+2\frac{Æ(x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}})-Æ(x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\tilde{U}^j_\beta \mathrm{w}})}{x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\beta \mathrm{w}}}+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{x_\sigma\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+3\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^j_\beta \mathrm{w}}})-x_{\tilde{U}^j_\beta \mathrm{w}}\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^j_\beta \mathrm{w}}})}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})(x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})}+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{x_{\kappa^-_\eta \mathrm{w}}x_\sigma(\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma}))}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)$$

$$+\frac{16}{3}a_+^{(c)}b_-^{(c)}c_-^{(c)}d_+^{(c)}\Big(-2(x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})\sum_{\sigma=\tilde{U}^i_\alpha,\kappa^-_\eta,\kappa^-_\lambda}\frac{\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\sum_{\sigma=\tilde{U}^i_\alpha,\kappa^-_\eta,\kappa^-_\lambda}\frac{x_\sigma(2\ln x_\sigma-3\ln^2x_\sigma-2\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma}))}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+2\frac{\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\kappa^-_\lambda \mathrm{w}}})}{-x_{\kappa^-_\eta \mathrm{w}}+x_{\kappa^-_\lambda \mathrm{w}}}$$

$$-\frac{x_{\kappa^-_\eta \mathrm{w}}\ln^2x_{\kappa^-_\eta \mathrm{w}}}{(-x_{\kappa^-_\eta \mathrm{w}}+x_{\kappa^-_\lambda \mathrm{w}})(-x_{\kappa^-_\eta \mathrm{w}}+x_{\tilde{U}^i_\alpha \mathrm{w}})}-\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}\ln^2x_{\tilde{U}^i_\alpha \mathrm{w}}}{(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})}\Big)$$

$$-\frac{2}{3}a_+^{(c)}b_-^{(c)}c_+^{(c)}d_-^{(c)}\Big(-\frac{-Æ(x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\lambda \mathrm{w}})+Æ(x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\tilde{U}^j_\beta \mathrm{w}})}{(-x_{\kappa^-_\lambda \mathrm{w}}+x_{\tilde{U}^j_\beta \mathrm{w}})}+\frac{-\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}})+\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}})}{-x_{\kappa^-_\eta \mathrm{w}}+x_{\tilde{U}^i_\alpha \mathrm{w}}}$$

$$+\frac{x_{\kappa^-_\eta \mathrm{w}}+x_{\kappa^-_\lambda \mathrm{w}}}{(-x_{\kappa^-_\eta \mathrm{w}}+x_{\tilde{U}^i_\alpha \mathrm{w}})(-x_{\kappa^-_\lambda \mathrm{w}}+x_{\tilde{U}^j_\beta \mathrm{w}})}\Big(-\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}})-\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}})+\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}})\Big)$$

$$-\frac{1}{(-x_{\kappa^-_\eta \mathrm{w}}+x_{\tilde{U}^i_\alpha \mathrm{w}})(-x_{\kappa^-_\lambda \mathrm{w}}+x_{\tilde{U}^j_\beta \mathrm{w}})}\Big(x_{\kappa^-_\eta \mathrm{w}}(\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}})-\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}}))-x_{\tilde{U}^i_\alpha \mathrm{w}}(\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}})-\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}}))\Big)\Big)$$

$$+\frac{16}{3}a_+^{(c)}b_-^{(c)}c_+^{(c)}d_-^{(c)}\Big(\sum_{\sigma=\tilde{U}^i_\alpha,\kappa^-_\eta,\kappa^-_\lambda}\Big(\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}^2x_\sigma(-2\ln x_\sigma-16\ln^2x_\sigma-3\ln^2(x_\sigma x_{\tilde{U}^i_\alpha \mathrm{w}}))}{4(x_\sigma-x_{\tilde{U}^i_\alpha \mathrm{w}})^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}x_\sigma(3\ln x_\sigma+12\ln^2x_\sigma-\ln^2(x_\sigma x_{\tilde{U}^i_\alpha \mathrm{w}}))}{2(x_\sigma-x_{\tilde{U}^i_\alpha \mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}-\frac{2x_\sigma\ln^2x_\sigma}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)$$

$$
+\frac{x^3_{\tilde{U}^i_\alpha \mathrm{w}}(\ln x_{\tilde{U}^i_\alpha \mathrm{w}} + 14\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}})}{2(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})^2} + \frac{x^2_{\tilde{U}^i_\alpha \mathrm{w}}(1 + 29\ln x_{\tilde{U}^i_\alpha \mathrm{w}} + 28\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}})}{2(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})}
$$

$$
+\frac{x^3_{\tilde{U}^i_\alpha \mathrm{w}}(\ln x_{\tilde{U}^i_\alpha \mathrm{w}} + 14\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}})}{2(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})^2(x_{\tilde{U}^j_\beta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})} + \frac{x^3_{\tilde{U}^i_\alpha \mathrm{w}}(\ln x_{\tilde{U}^i_\alpha \mathrm{w}} + 14\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}})}{2(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})^2(x_{\kappa^-_\lambda \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})}
$$

$$
-\frac{x_{\kappa^-_\eta \mathrm{w}}\ln x_{\kappa^-_\eta \mathrm{w}}}{(x_{\kappa^-_\lambda \mathrm{w}} - x_{\kappa^-_\eta \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}} - x_{\kappa^-_\eta \mathrm{w}})} + 2\frac{x_{\kappa^-_\lambda \mathrm{w}}\ln x_{\kappa^-_\lambda \mathrm{w}}}{(x_{\kappa^-_\eta \mathrm{w}} - x_{\kappa^-_\lambda \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}} - x_{\kappa^-_\lambda \mathrm{w}})} - \frac{3x_{\kappa^-_\lambda \mathrm{w}}\ln x_{\kappa^-_\lambda \mathrm{w}}}{(x_{\kappa^-_\eta \mathrm{w}} - x_{\kappa^-_\lambda \mathrm{w}})^2}\Big)
$$

$$
+\frac{16}{3}a^{(c)}_+ b^{(c)}_- c^{(c)}_+ d^{(c)}_- \Big(\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^j_\beta,\kappa^-_\eta,\kappa^-_\lambda}\frac{x_{\kappa^-_\lambda \mathrm{w}}x_\sigma(6\ln x_\sigma - 7\ln^2 x_\sigma)}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} + \sum_{\sigma=\tilde{U}^i_\alpha,\kappa^-_\eta,\kappa^-_\lambda}\frac{x_\sigma(3\ln x_\sigma + 7\ln^2 x_\sigma)}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}
$$

$$
-\frac{x_{\kappa^-_\eta \mathrm{w}}x_{\kappa^-_\lambda \mathrm{w}}(3\ln x_{\kappa^-_\eta \mathrm{w}} + \ln^2 x_{\kappa^-_\eta \mathrm{w}})}{2(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})^2} + \frac{4x_{\kappa^-_\eta \mathrm{w}}x_{\kappa^-_\lambda \mathrm{w}}\ln^2 x_{\kappa^-_\eta \mathrm{w}}}{2(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^j_\beta \mathrm{w}})}
$$

$$
+\sum_{\sigma=\tilde{U}^i_\alpha,U^j_\beta,\kappa^-_\eta,\kappa^-_\lambda}\Big(\frac{(x_{\kappa^-_\lambda \mathrm{w}} + x_{\tilde{U}^j_\beta \mathrm{w}})x_{\kappa^-_\lambda \mathrm{w}}x_\sigma\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} - \frac{3x_{\kappa^-_\lambda \mathrm{w}}x_\sigma\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}\Big)
$$

$$
+\sum_{\sigma=\tilde{U}^i_\alpha,U^j_\beta,\kappa^-_\eta}\Big(\frac{(x_{\kappa^-_\lambda \mathrm{w}} + x_{\tilde{U}^j_\beta \mathrm{w}} + x_{\kappa^-_\lambda \mathrm{w}})x_\sigma\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} + \frac{3x_\sigma\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}\Big) + \frac{\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}})}{x_{\tilde{U}^i_\alpha \mathrm{w}} - x_{\tilde{U}^j_\beta \mathrm{w}}}\Big), \tag{81}
$$

$$
cc_2 = \frac{1}{24}(a^{(c)}_- b^{(c)}_+ c^{(c)}_+ d^{(c)}_- + a^{(c)}_+ b^{(c)}_- c^{(c)}_- d^{(c)}_+)\Big(F^{2a}_A + F^{2b}_A + \frac{3}{2}F^{2c}_A + 6F^{2d}_A
$$

$$
-\frac{5}{2}F^{2e}_A + \frac{1}{2}F^{2f}_A\Big)(x_{\kappa^-_\lambda \mathrm{w}}, x_{\tilde{U}^i_\alpha \mathrm{w}}, x_{\tilde{U}^j_\beta \mathrm{w}}, 0, x_{\kappa^-_\eta \mathrm{w}}, x_{\tilde{U}^i_\alpha \mathrm{w}}, x_{\tilde{U}^j_\beta \mathrm{w}})
$$

$$
+\Big(a^{(c)}_- b^{(c)}_+ c^{(c)}_+ d^{(c)}_- + a^{(c)}_+ b^{(c)}_- c^{(c)}_- d^{(c)}_+\Big)\Big[\Big(\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}}) - \mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^j_\beta \mathrm{w}}})}{x_{\tilde{U}^i_\alpha \mathrm{w}} - x_{\tilde{U}^j_\beta \mathrm{w}}} + \sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{4\Big(x_\sigma - x_{\kappa^-_\lambda \mathrm{w}}\Big)\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})}{3\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}
$$

$$
+\frac{7}{48}\frac{-x_{\kappa^-_\eta \mathrm{w}}(-\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}}) + \Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\kappa^-_\eta \mathrm{w}}})) + x_{\tilde{U}^i_\alpha \mathrm{w}}(-\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}}) + \Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}}))}{(x_{\kappa^-_\eta \mathrm{w}} - x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}} - x_{\tilde{U}^j_\beta \mathrm{w}})}\Big)
$$

$$
-\frac{1}{48}\Big(-\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{x_\sigma(x_{\kappa^-_\lambda \mathrm{w}}\ln^2(x_\sigma x_{\kappa^-_\lambda \mathrm{w}}) - x_{\tilde{U}^j_\beta \mathrm{w}}\ln^2(x_\sigma x_{\tilde{U}^j_\beta \mathrm{w}}))}{2(x_{\kappa^-_\lambda \mathrm{w}} - x_{\tilde{U}^j_\beta \mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}
$$

$$
+\frac{x^2_{\tilde{U}^j_\beta \mathrm{w}} + 2x_{\kappa^-_\lambda \mathrm{w}}x_{\tilde{U}^j_\beta \mathrm{w}} - 2x^2_{\kappa^-_\lambda \mathrm{w}}}{x_{\kappa^-_\lambda \mathrm{w}} - x_{\tilde{U}^j_\beta \mathrm{w}}}\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma}) - \mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} + 2\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\eta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}}) - \mathcal{R}_{i_2}(\frac{x_{\kappa^-_\eta \mathrm{w}}}{x_{\tilde{U}^j_\beta \mathrm{w}}})}{x_{\tilde{U}^i_\alpha \mathrm{w}} - x_{\tilde{U}^j_\beta \mathrm{w}}}
$$

$$
+(x_{\tilde{U}^j_\beta \mathrm{w}}+2x_{\kappa^-_\eta \mathrm{w}})\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+2\frac{\text{Æ}(x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}})-\text{Æ}(x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\tilde{U}^j_\beta \mathrm{w}})}{x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\beta \mathrm{w}}}
$$

$$
+3\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^j_\beta \mathrm{w}}})-x_{\tilde{U}^j_\beta \mathrm{w}}\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_{\tilde{U}^j_\beta \mathrm{w}}})}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})(x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})}+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{x_{\kappa^-_\eta \mathrm{w}}x_\sigma(\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})-\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma}))}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta}\frac{x_\sigma\Upsilon(\frac{x_{\kappa^-_\lambda \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)-\frac{8}{3}\Big(\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^j_\beta,\kappa^-_\eta}\frac{x_\sigma(-10\ln x_\sigma+7\ln^2 x_\sigma)}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\lambda}\frac{x_\sigma(10\ln x_\sigma-7\ln^2 x_\sigma)}{2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta,\kappa^-_\eta,\kappa^-_\lambda}\frac{(x^2_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}}x_{\kappa^-_\lambda \mathrm{w}})x_\sigma\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
-\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^i_\beta}\frac{(x_{\kappa^-_\eta \mathrm{w}}+x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}})x_\sigma\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^j_\beta,\kappa^-_\eta,\kappa^-_\lambda}\frac{3x_{\kappa^-_\lambda \mathrm{w}}x_\sigma\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\sum_{\sigma=\tilde{U}^i_\alpha,\tilde{U}^j_\beta,\kappa^-_\eta}\frac{3x_\sigma\Upsilon(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\frac{\mathcal{R}_{i_2}(\frac{x_{\tilde{U}^j_\beta \mathrm{w}}}{x_{\tilde{U}^i_\alpha \mathrm{w}}})}{x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^j_\beta \mathrm{w}}}+\frac{x_{\kappa^-_\eta \mathrm{w}}x_{\kappa^-_\lambda \mathrm{w}}(\ln x_{\kappa^-_\eta \mathrm{w}}-\ln^2 x_{\kappa^-_\eta \mathrm{w}})}{2(-x_{\kappa^-_\eta \mathrm{w}}+x_{\kappa^-_\lambda \mathrm{w}})(-x_{\kappa^-_\eta \mathrm{w}}+x_{\tilde{U}^i_\alpha \mathrm{w}})^2}
$$

$$
+\frac{x_{\kappa^-_\eta \mathrm{w}}x_{\kappa^-_\lambda \mathrm{w}}(9\ln x_{\kappa^-_\eta \mathrm{w}}-6\ln^2 x_{\kappa^-_\eta \mathrm{w}})}{2(-x_{\kappa^-_\eta \mathrm{w}}+x_{\kappa^-_\lambda \mathrm{w}})(-x_{\kappa^-_\eta \mathrm{w}}+x_{\tilde{U}^i_\alpha \mathrm{w}})(-x_{\kappa^-_\eta \mathrm{w}}+x_{\tilde{U}^j_\beta \mathrm{w}})}+\sum_{\sigma=\tilde{U}^j_\beta,\kappa^-_\eta,\kappa^-_\lambda}\Big(\frac{x_\sigma(3\ln x_\sigma-2\ln^2 x_\sigma)}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{x^2_{\tilde{U}^i_\alpha \mathrm{w}}x_\sigma(22\ln x_\sigma-16\ln^2 x_\sigma+\ln^2(x_{\tilde{U}^i_\alpha \mathrm{w}}x_\sigma))}{4(-x_\sigma+x_{\tilde{U}^i_\alpha \mathrm{w}})^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}-\frac{x^2_{\tilde{U}^i_\alpha \mathrm{w}}x_\sigma(17\ln x_\sigma-12\ln^2 x_\sigma+\ln^2(x_{\tilde{U}^i_\alpha \mathrm{w}}x_\sigma))}{2(-x_\sigma+x_{\tilde{U}^i_\alpha \mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)
$$

$$
-\frac{15x^2_{\tilde{U}^i_\alpha \mathrm{w}}\ln x_{\tilde{U}^i_\alpha \mathrm{w}}-6x^2_{\tilde{U}^i_\alpha \mathrm{w}}\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}}+11x^2_{\tilde{U}^i_\alpha \mathrm{w}}}{2(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})}-\frac{11x^2_{\tilde{U}^i_\alpha \mathrm{w}}\ln x_{\tilde{U}^i_\alpha \mathrm{w}}-6x^3_{\tilde{U}^i_\alpha \mathrm{w}}\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}}}{2(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})^2}
$$

$$
+\frac{x^3_{\tilde{U}^i_\alpha \mathrm{w}}(6\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}}-11\ln x_{\tilde{U}^i_\alpha \mathrm{w}})}{2(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})^2(x_{\tilde{U}^j_\beta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})}+\frac{x^3_{\tilde{U}^i_\alpha \mathrm{w}}(6\ln^2 x_{\tilde{U}^i_\alpha \mathrm{w}}-11\ln x_{\tilde{U}^i_\alpha \mathrm{w}})}{2(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})^2(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})}
$$

$$
+\frac{x_{\kappa^-_\lambda \mathrm{w}}\ln x_{\kappa^-_\lambda \mathrm{w}}}{(x_{\kappa^-_\eta \mathrm{w}}-x_{\kappa^-_\lambda \mathrm{w}})^2}-\frac{x_{\kappa^-_\lambda \mathrm{w}}\ln x_{\kappa^-_\lambda \mathrm{w}}}{(x_{\kappa^-_\eta \mathrm{w}}-x_{\kappa^-_\lambda \mathrm{w}})(x_{\tilde{U}^j_\beta \mathrm{w}}-x_{\kappa^-_\lambda \mathrm{w}})}-\sum_{\sigma=\tilde{U}^j_\beta,\kappa^-_\eta,\kappa^-_\lambda}\Big(\frac{2x_\sigma\Upsilon(\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}
$$

$$
+\frac{4x^4_{\tilde{U}^i_\alpha \mathrm{w}}x_\sigma\Upsilon(\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}}{x_\sigma})}{(-x_\sigma+x_{\tilde{U}^i_\alpha \mathrm{w}})^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}-\frac{6x_{\tilde{U}^i_\alpha \mathrm{w}}x_\sigma\Upsilon(\frac{x_{\tilde{U}^i_\alpha \mathrm{w}}}{x_\sigma})}{(-x_\sigma+x_{\tilde{U}^i_\alpha \mathrm{w}})\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)\Big)\Big]
$$

$$
+\Big(a_+^{(c)} b_+^{(c)} c_-^{(c)} d_-^{(c)} + a_-^{(c)} b_-^{(c)} c_+^{(c)} d_+^{(c)}\Big)\sqrt{x_{\kappa_\eta^-\mathrm{w}} x_{\kappa_\lambda^-\mathrm{w}}}\Big[\frac{4}{3}\Big(-\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^i,\kappa_\eta^-} \frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}
$$

$$
+\frac{x_{\kappa_\eta^-\mathrm{w}} - x_{\tilde{U}_\beta^j\mathrm{w}}}{x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\beta^j\mathrm{w}}} \sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^i,\kappa_\eta^-} \frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_\sigma}) - \mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} + \frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\tilde{U}_\alpha^i\mathrm{w}}}) - \mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\tilde{U}_\beta^j\mathrm{w}}}) - \mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j\mathrm{w}}}{x_{\tilde{U}_\alpha^i\mathrm{w}}})}{(x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\beta^j\mathrm{w}})(x_{\tilde{U}_\alpha^i\mathrm{w}} - x_{\tilde{U}_\beta^j\mathrm{w}})}\Big)
$$

$$
-\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\kappa_\eta^-\mathrm{w}}}) + \mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\tilde{U}_\alpha^i\mathrm{w}}}) + \mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\alpha^i\mathrm{w}}}{x_{\kappa_\eta^-\mathrm{w}}}) - \mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j\mathrm{w}}}{x_{\tilde{U}_\alpha^i\mathrm{w}}})}{2(x_{\tilde{U}_\alpha^i\mathrm{w}} - x_{\kappa_\eta^-\mathrm{w}})(x_{\tilde{U}_\beta^j\mathrm{w}} - x_{\kappa_\lambda^-\mathrm{w}})} + \frac{28}{3}\Big(\sum_{\sigma=\tilde{U}_\beta^j,\kappa_\eta^-,\kappa_\lambda^-}\Big(\frac{2x_{\tilde{U}_\alpha^i\mathrm{w}}(x_\sigma \ln x_\sigma - \ln^2 x_\sigma)}{(x_{\tilde{U}_\alpha^i\mathrm{w}} - x_\sigma)\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}
$$

$$
-\frac{x_\sigma(2\ln x_\sigma - \ln^2 x_\sigma)}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} - \frac{2x_\sigma x_{\tilde{U}_\alpha^i\mathrm{w}}\Upsilon(\frac{x_{\tilde{U}_\alpha^i\mathrm{w}}}{x_\sigma})}{(x_{\tilde{U}_\alpha^i\mathrm{w}} - x_\sigma)\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} + \frac{x_\sigma\Upsilon(\frac{x_{\tilde{U}_\alpha^i\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}\Big)
$$

$$
+\frac{-2x_{\tilde{U}_\alpha^i\mathrm{w}} + x_{\tilde{U}_\alpha^i\mathrm{w}}\ln x_{\tilde{U}_\alpha^i\mathrm{w}} + 3x_{\tilde{U}_\alpha^i\mathrm{w}}\ln^2 x_{\tilde{U}_\alpha^i\mathrm{w}}}{(x_{\kappa_\eta^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\tilde{U}_\beta^j\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})} + \frac{-2x^2_{\tilde{U}_\alpha^i\mathrm{w}}(\ln x_{\tilde{U}_\alpha^i\mathrm{w}} + \ln^2 x_{\tilde{U}_\alpha^i\mathrm{w}})}{(x_{\kappa_\eta^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\tilde{U}_\beta^j\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})^2}
$$

$$
+\frac{-2x^2_{\tilde{U}_\alpha^i\mathrm{w}}(\ln x_{\tilde{U}_\alpha^i\mathrm{w}} + \ln^2 x_{\tilde{U}_\alpha^i\mathrm{w}})}{(x_{\kappa_\eta^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})^2(x_{\tilde{U}_\beta^j\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})} + \frac{-2x^2_{\tilde{U}_\alpha^i\mathrm{w}}(\ln x_{\tilde{U}_\alpha^i\mathrm{w}} + \ln^2 x_{\tilde{U}_\alpha^i\mathrm{w}})}{(x_{\kappa_\eta^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})^2(x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\tilde{U}_\beta^j\mathrm{w}} - x_{\tilde{U}_\alpha^i\mathrm{w}})}\Big)
$$

$$
-\frac{16}{3}\Big(-\frac{x_{\kappa_\eta^-\mathrm{w}}\ln^2 x_{\kappa_\eta^-\mathrm{w}}}{2(-x_{\kappa_\eta^-\mathrm{w}} + x_{\kappa_\lambda^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}} + x_{\tilde{U}_\alpha^i\mathrm{w}})^2} + \frac{4x_{\kappa_\eta^-\mathrm{w}}\ln^2 x_{\kappa_\eta^-\mathrm{w}}}{(-x_{\kappa_\eta^-\mathrm{w}} + x_{\kappa_\lambda^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}} + x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}} + x_{\tilde{U}_\beta^j\mathrm{w}})}
$$

$$
+\sum_{\sigma=\tilde{U}_\alpha^i\tilde{U}_\beta^j,\kappa_\eta^-,\kappa_\lambda^-}\Big(\frac{x_\sigma(6\ln x_\sigma - 7\ln^2 x_\sigma)}{2\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} + \frac{(x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\beta^j\mathrm{w}})x_\sigma\mathcal{R}_{i_2}(\frac{\tilde{U}_\beta^j}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} - 3\frac{x_\sigma\Upsilon(\frac{\tilde{U}_\beta^j}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}\Big)
$$

$$
-\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^j,\kappa_\eta^-}\frac{x_\sigma\mathcal{R}_{i_2}(\frac{\tilde{U}_\beta^j}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}\Big)\Big], \tag{82}
$$

$$
cc_3 = -2cc_2 , \tag{83}
$$

$$
cc_4 = a_-^{(c)} b_-^{(c)} c_-^{(c)} d_-^{(c)}\sqrt{x_{\kappa_\eta^-\mathrm{w}} x_{\kappa_\lambda^-\mathrm{w}}}\Big(\frac{4\Big(\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\kappa_\eta^-\mathrm{w}}}) + \mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_{\tilde{U}_\alpha^i\mathrm{w}}}) + \mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j\mathrm{w}}}{x_{\kappa_\eta^-\mathrm{w}}}) - \mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j\mathrm{w}}}{x_{\tilde{U}_\alpha^i\mathrm{w}}})\Big)}{3(-x_{\kappa_\eta^-\mathrm{w}} + x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}} + x_{\tilde{U}_\beta^j\mathrm{w}})}
$$

$$
-\frac{2}{3}\Big(-\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^i,\kappa_\eta^-}\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)} + \frac{x_{\kappa_\eta^-\mathrm{w}} - x_{\tilde{U}_\beta^j\mathrm{w}}}{x_{\kappa_\lambda^-\mathrm{w}} - x_{\tilde{U}_\beta^j\mathrm{w}}}\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^i,\kappa_\eta^-}\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-\mathrm{w}}}{x_\sigma}) - \mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j\mathrm{w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho - x_\sigma)}
$$

$$+\frac{\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-{\rm w}}}{x_{\tilde{U}_\alpha^i{\rm w}}})-\mathcal{R}_{i_2}(\frac{x_{\kappa_\lambda^-{\rm w}}}{x_{\tilde{U}_\beta^j{\rm w}}})-\mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j{\rm w}}}{x_{\tilde{U}_\alpha^i{\rm w}}})}{(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde{U}_\beta^j{\rm w}})(x_{\tilde{U}_\alpha^i{\rm w}}-x_{\tilde{U}_\beta^j{\rm w}})}\Big)-\frac{64}{3}\Big(-\sum_{\sigma=\tilde{U}_\beta^j,\kappa_\eta^-,\kappa_\lambda^-}\frac{2x_{\tilde{U}_\alpha^i{\rm w}}x_\sigma(\ln x_\sigma-\ln^2x_\sigma)}{(-x_\sigma+x_{\tilde{U}_\alpha^i{\rm w}})^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\frac{x_{\tilde{U}_\alpha^i{\rm w}}(2-\ln x_{\tilde{U}_\alpha^i{\rm w}}-3\ln^2x_{\tilde{U}_\alpha^i{\rm w}})}{(x_{\kappa_\eta^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})(x_{\tilde{U}_\beta^j{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})}+\frac{2x^2_{\tilde{U}_\alpha^i{\rm w}}(\ln x_{\tilde{U}_\alpha^i{\rm w}}-\ln^2x_{\tilde{U}_\alpha^i{\rm w}})}{(x_{\kappa_\eta^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})(x_{\tilde{U}_\beta^j{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})^2}$$

$$+\frac{2x^2_{\tilde{U}_\alpha^i{\rm w}}(\ln x_{\tilde{U}_\alpha^i{\rm w}}-\ln^2x_{\tilde{U}_\alpha^i{\rm w}})}{(x_{\kappa_\eta^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})^2(x_{\tilde{U}_\beta^j{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})}+\frac{2x^2_{\tilde{U}_\alpha^i{\rm w}}(\ln x_{\tilde{U}_\alpha^i{\rm w}}-\ln^2x_{\tilde{U}_\alpha^i{\rm w}})}{(x_{\kappa_\eta^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})^2(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})(x_{\tilde{U}_\beta^j{\rm w}}-x_{\tilde{U}_\alpha^i{\rm w}})}$$

$$+\sum_{\sigma=\tilde{U}_\beta^j,\kappa_\eta^-,\kappa_\lambda^-}\frac{(x_{\tilde{U}_\alpha^i{\rm w}}+x_\sigma)x_\sigma\Upsilon(\frac{x_{\tilde{U}_\alpha^i{\rm w}}}{x_\sigma})}{(-x_\sigma+x_{\tilde{U}_\alpha^i{\rm w}})^2\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)$$

$$+\frac{32}{3}\Big(\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^j,\kappa_\eta^-,\kappa_\lambda^-}\frac{x_\sigma(-3\ln x_\sigma+7\ln^2x_\sigma)}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\frac{x_{\kappa_\eta^-{\rm w}}\ln^2x_{\kappa_\eta^-{\rm w}}}{2(-x_{\kappa_\eta^-{\rm w}}+x_{\kappa_\lambda^-{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{\tilde{U}_\alpha^i{\rm w}})^2}$$

$$-\frac{4x_{\kappa_\eta^-{\rm w}}\ln^2x_{\kappa_\eta^-{\rm w}}}{(-x_{\kappa_\eta^-{\rm w}}+x_{\kappa_\lambda^-{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{\tilde{U}_\alpha^i{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{\tilde{U}_\beta^j{\rm w}})}+\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^j,\kappa_\eta^-}\frac{x_\sigma\mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j{\rm w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}$$

$$+\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^j,\kappa_\eta^-,\kappa_\lambda^-}\frac{x_\sigma(-x_{\kappa_\lambda^-{\rm w}}+x_{\tilde{U}_\beta^j{\rm w}})\mathcal{R}_{i_2}(\frac{x_{\tilde{U}_\beta^j{\rm w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}+\sum_{\sigma=\tilde{U}_\alpha^i,\tilde{U}_\beta^j,\kappa_\eta^-,\kappa_\lambda^-}\frac{3x_\sigma\Upsilon(\frac{x_{\tilde{U}_\beta^j{\rm w}}}{x_\sigma})}{\prod\limits_{\rho\neq\sigma}(x_\rho-x_\sigma)}\Big)\Big)\;, \tag{84}$$

$$cc_5=\frac{1}{4}cc_4\;. \tag{85}$$

In the above expressions Eqs.(81,82,83,84,85), the coupling constants are defined as

$$a_+^{(c)}=\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1l}+\frac{m_{u^i}}{\sqrt{2}m_{\rm w}\sin\beta}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2l}\Big)\;,$$

$$a_-^{(c)}=\frac{h_d}{\sqrt{2}}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2l}\;,$$

$$b_+^{(c)}=\frac{h_b}{\sqrt{2}}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2l}\;,$$

$$b_-^{(c)}=\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1l}+\frac{m_{u^j}}{\sqrt{2}m_{\rm w}\sin\beta}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2l}\Big)\;,$$

$$c_+^{(c)}=\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1k}+\frac{m_{u^j}}{\sqrt{2}m_{\rm w}\sin\beta}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2k}\Big)\;,$$

$$c_-^{(c)}=\frac{h_d}{\sqrt{2}}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2k}\;,$$

$$d_+^{(c)}=\frac{h_b}{\sqrt{2}}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2k}\;,$$

$$d_-^{(c)} = \Big(- \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_+^{1k} + \frac{m_{u^i}}{\sqrt{2} m_{\rm w} \sin\beta} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_+^{2k} \Big) \; . \tag{86}$$

D.2 The corrections due to gluino contributions

The corrections caused by gluino can be written as

$$\phi_\alpha^{\tilde{g}} = \phi_\alpha^{ww\tilde{g}} + 2\phi_\alpha^{wh\tilde{g}} + \phi_\alpha^{hh\tilde{g}} + \phi_\alpha^{sw\tilde{g}} + \phi_\alpha^{sh\tilde{g}} + \phi_\alpha^{p\tilde{g}} \tag{87}$$

with

$$\begin{aligned}
\phi_1^{ww\tilde{g}} =& \mathcal{Z}_{\tilde{D}^3}^{1\gamma} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \Big(\frac{4}{3} F_A^{2a} + \frac{16}{3} F_A^{2b} - 4F_A^{2d} - \frac{4}{3} F_A^{2e} - \frac{16}{3} F_A^{2f} \Big)(x_{j\rm w}, 1, 1, x_{\tilde{U}_\alpha^i \rm w}, x_{\tilde{D}_\delta^1 \rm w}, x_{\tilde{D}_\gamma^3 \rm w}, x_{\tilde{g}\rm w}) \\
&+ \frac{16}{3} (\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2 \Big) \Big(F_C^{2a} + F_C^{2d} - F_C^{2e} \Big)(x_{j\rm w}, x_{i\rm w}, x_{i\rm w}, 1, 1, x_{\tilde{U}_\alpha^i \rm w}, x_{\tilde{g}\rm w}) \\
&- \frac{16}{3} \mathcal{Z}_{\tilde{D}^3}^{1\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{D}^3}^{1\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \Big(F_D^{2e} - F_D^{2a} - F_D^{2d} \Big)(x_{i\rm w}, x_{j\rm w}, 1, 1, x_{\tilde{U}_\alpha^i \rm w}, x_{\tilde{D}_\delta^1 \rm w}, x_{\tilde{g}\rm w}) \\
&- \frac{64}{3} \sqrt{x_{\tilde{g}\rm w} x_{i\rm w}} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} F_C^{1a}(x_{j\rm w}, x_{i\rm w}, x_{i\rm w}, 1, 1, x_{\tilde{U}_\alpha^i \rm w}, x_{\tilde{g}\rm w}) \\
&+ \frac{32}{3} \sqrt{x_{\tilde{g}\rm w} x_{i\rm w}} \mathcal{Z}_{\tilde{D}^3}^{1\delta} \mathcal{Z}_{\tilde{D}^3}^{1\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \Big(F_D^{1b} - F_D^{1c} \Big)(x_{i\rm w}, x_{j\rm w}, 1, 1, x_{\tilde{U}_\alpha^i \rm w}, x_{\tilde{D}_\delta^1 \rm w}, x_{\tilde{g}\rm w}) \\
&+ \frac{16}{3} x_{i\rm w} (\mathcal{Z}_{\tilde{U}^i}^{2\alpha})^2 \Big(F_C^{1a} + F_C^{1b} - F_C^{1c} \Big)(x_{j\rm w}, x_{i\rm w}, x_{i\rm w}, 1, 1, x_{\tilde{U}_\alpha^i \rm w}, x_{\tilde{g}\rm w}) \\
&+ \frac{56}{3} \Big(\frac{x_{i\rm w} \ln x_{i\rm w}}{(-x_{i\rm w} + x_{j\rm w})^2} + \frac{x_{i\rm w} \ln x_{i\rm w}}{(1-x_{i\rm w})^2 (-x_{i\rm w} + x_{j\rm w})^2} - \frac{2x_{i\rm w} \ln x_{i\rm w}}{(1-x_{i\rm w})(-x_{i\rm w} + x_{j\rm w})^2} + \frac{\ln x_{i\rm w}}{-x_{i\rm w} + x_{j\rm w}} \\
&+ \frac{\ln x_{i\rm w}}{(1-x_{i\rm w})^2(-x_{i\rm w} + x_{j\rm w})} + \frac{2x_{i\rm w} \ln x_{i\rm w}}{(1-x_{i\rm w})^3(-x_{i\rm w} + x_{j\rm w})} - \frac{2x_{i\rm w} \ln x_{i\rm w}}{(1-x_{i\rm w})^2(-x_{i\rm w} + x_{j\rm w})} \\
&- \frac{2\ln x_{i\rm w}}{(1-x_{i\rm w})(-x_{i\rm w} + x_{j\rm w})} \Big) - \frac{64}{3} \frac{x_{i\rm w}^2 \ln x_{i\rm w}}{(1-x_{i\rm w})^2(-x_{i\rm w} + x_{j\rm w})} + \frac{16 x_{i\rm w}^2 \ln x_{i\rm w}}{(1-x_{i\rm w})^2(-x_{i\rm w} + x_{j\rm w})} \\
&- \frac{56}{3} \frac{x_{j\rm w}^3 \ln x_{j\rm w}}{(1-x_{j\rm w})^2 (x_{i\rm w} - x_{j\rm w})^2} + \frac{64}{3} \frac{x_{j\rm w}^2 \ln x_{j\rm w}}{(1-x_{j\rm w})^2 (x_{i\rm w} - x_{j\rm w})} + \frac{16 x_{j\rm w}^2 \ln x_{j\rm w}}{(1-x_{j\rm w})^2 (x_{i\rm w} - x_{j\rm w})} + (i \leftrightarrow j) \; ,
\end{aligned} \tag{88}$$

$$\begin{aligned}
\phi_2^{ww\tilde{g}} =& \mathcal{Z}_{\tilde{D}^3}^{2\gamma} \mathcal{Z}_{\tilde{D}^1}^{2\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \Big(\frac{2}{3} F_A^{2a} + \frac{8}{3} F_A^{2b} - 2F_A^{2d} - \frac{2}{3} F_A^{2e} - \frac{8}{3} F_A^{2f} \Big)(x_{j\rm w}, 1, 1, x_{\tilde{U}_\alpha^i \rm w}, x_{\tilde{D}_\delta^1 \rm w}, x_{\tilde{D}_\gamma^3 \rm w}, x_{\tilde{g}\rm w}) \\
&+ (i \leftrightarrow j) \; ,
\end{aligned} \tag{89}$$

$$\phi_3^{ww\tilde{g}} = -2\phi_2^{ww\tilde{g}} \; , \tag{90}$$

$$\phi_1^{wh\tilde{g}} = -\frac{64}{3\sin^2\beta} (\mathcal{Z}_H^{2k})^2 \frac{x_{i\rm w}^{\frac{5}{2}} x_{j\rm w}^{\frac{3}{2}}}{(1-x_{i\rm w})(x_{H_k^- \rm w} - x_{i\rm w})(-x_{i\rm w} + x_{j\rm w})}$$

$$-\frac{16}{3\sin^2\beta}(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2\Big(F_C^{1a}+F_C^{1b}-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{32}{3\sin^2\beta}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}x_{i\mathrm{w}}^2x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}F_C^0(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{32}{3\sin^2\beta}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{16}{3\sin^2\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_{\tilde{U}^i}^{2\alpha})^2(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}\Big(F_C^{1a}+F_C^{1b}-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{8}{3\sin^2\beta}(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}(\mathcal{Z}_H^{2k})^2\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}+\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\Big)\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\Big(F_D^{1a}-F_D^{1b}$$

$$-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{64}{3\sin^2\beta}(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}(\mathcal{Z}_H^{2k})^2\frac{x_{H_k^-\mathrm{w}}^2\ln x_{H_k^-\mathrm{w}}}{(1-x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+(\mathcal{Z}_H^{2k})^2(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}\frac{8x_{H_k^-\mathrm{w}}\ln x_{H_k^-\mathrm{w}}}{\sin^2\beta(1-x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{4}{3}h_d\mathcal{E}^{ib}\sqrt{x_{i\mathrm{w}}}\mathcal{Z}_H^{1j}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{H_j^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{64}{3\sin^2\beta}(\mathcal{Z}_H^{2k})^2\Big(-x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}+x_{i\mathrm{w}}^5x_{j\mathrm{w}}+2x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2-x_{i\mathrm{w}}^3x_{j\mathrm{w}}^2-x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}^2\Big)$$

$$\frac{\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\ln x_{i\mathrm{w}}}{(1-x_{i\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(-x_{i\mathrm{w}}+x_{j\mathrm{w}})^2}+\frac{8}{\sin^2\beta}(\mathcal{Z}_H^{2k})^2\Big(\frac{8x_{i\mathrm{w}}^{\frac{3}{2}}x_{j\mathrm{w}}^{\frac{7}{2}}\ln x_{j\mathrm{w}}}{(1-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}$$

$$+\frac{x_{i\mathrm{w}}^{\frac{5}{2}}x_{j\mathrm{w}}^{\frac{3}{2}}\ln x_{i\mathrm{w}}}{((1-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}+\frac{x_{i\mathrm{w}}^{\frac{3}{2}}x_{j\mathrm{w}}^{\frac{5}{2}}\ln x_{j\mathrm{w}}}{(1-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)$$

$$+(i\leftrightarrow j)\;, \tag{91}$$

$$\phi_2^{wh\tilde{g}}=-\frac{4}{3}h_bh_d\Big(\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}+\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\Big)(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^j}^{1\beta}$$

$$\Big(F_D^{1a}-3F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{4x_{i\mathrm{w}}x_{j\mathrm{w}}}{3\sin^2\beta}\Big(\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}+\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\Big)(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^j}^{1\beta}$$

$$\Big(F_D^{1a}-3F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{2}{3}h_d\sqrt{x_{i\mathrm{w}}}\mathcal{Z}_H^{1j}\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{E}^{ib}\Big(F_A^{1a}-3F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{H_j^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{4}{3}h_bh_d(\mathcal{Z}_H^{1k})^2\Big(\frac{x_{H_k^-\mathrm{w}}\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\ln x_{H_k^-\mathrm{w}}}{(1-x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}+\frac{x_{i\mathrm{w}}\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\ln x_{i\mathrm{w}}}{(1-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{x_{j\mathrm{w}}\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\ln x_{j\mathrm{w}}}{(1-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)-\frac{4}{3\sin^2\beta}(\mathcal{Z}_H^{2k})^2\Big(\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\ln x_{H_k^-\mathrm{w}}}{(1-x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{x_{i\mathrm{w}}^2x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\ln x_{i\mathrm{w}}}{(1-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}+\frac{x_{i\mathrm{w}}x_{j\mathrm{w}}^2\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\ln x_{j\mathrm{w}}}{(1-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\Big)$$

$$+\frac{4}{3}h_bh_d(\mathcal{Z}_H^{1k})^2\Big((\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2+(\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2\Big)\Big(F_C^{2a}+F_C^{2d}-F_C^{2e}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{16}{3}h_bh_d\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{8}{3\sin\beta}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\Big(h_dx_{i\mathrm{w}}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}+h_bx_{j\mathrm{w}}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\Big)\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^j}^{1\beta}$$

$$\Big(F_D^{2b}+F_D^{2d}-2F_D^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{16}{3\sin\beta}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\Big(h_bx_{j\mathrm{w}}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}+h_dx_{i\mathrm{w}}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\Big)\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{U}^j}^{1\beta}$$

$$\Big(F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{8}{3\sin\beta}\sqrt{x_{\tilde{g}\mathrm{w}}}x_{i\mathrm{w}}\mathcal{Z}_H^{2j}\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{E}^{ib}\Big(F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{H_j^-\mathrm{w}},1,x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-2h_bh_d(\mathcal{Z}_H^{1k})^2\frac{x_{H_k^-\mathrm{w}}^2(x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})\ln x_{H_k^-\mathrm{w}}}{(-1+x_{H_k^-\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{4}{3\sin\beta}h_d\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\frac{(x_{H_k^-\mathrm{w}}+2x_{\tilde{g}\mathrm{w}})x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}\ln x_{H_k^-\mathrm{w}}}{(1-x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+2h_bh_d(\mathcal{Z}_H^{1k})^2\Big(-2x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}+x_{i\mathrm{w}}^2+x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2+3x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}-2x_{i\mathrm{w}}x_{j\mathrm{w}}$$

$$-2x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}+x_{i\mathrm{w}}^2x_{j\mathrm{w}}\Big)\frac{x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(1-x_{H_k^-\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})^2}$$

$$-2h_bh_d(\mathcal{Z}_H^{1k})^2\Big(x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}-x_{i\mathrm{w}}^3-2x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}+x_{i\mathrm{w}}x_{j\mathrm{w}}$$

$$+x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}\Big)\frac{x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(-1+x_{i\mathrm{w}})^2(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}$$

$$-2h_bh_d(\mathcal{Z}_H^{1k})^2\frac{(x_{i\mathrm{w}}+x_{j\mathrm{w}})x_{j\mathrm{w}}^2\ln x_{j\mathrm{w}}}{(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{4}{3\sin\beta}h_d\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\frac{(-2x_{\tilde{g}\mathrm{w}}+3x_{j\mathrm{w}})x_{i\mathrm{w}}x_{j\mathrm{w}}\ln x_{j\mathrm{w}}}{(x_{i\mathrm{w}}-x_{j\mathrm{w}})(-1+x_{j\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+(i\leftrightarrow j)\ , \tag{92}$$

$$\phi_3^{wh\tilde{g}}=-2\phi_2^{wh\tilde{g}}\ , \tag{93}$$

$$\phi_4^{wh\tilde{g}} = -\frac{16}{3\sin\beta} h_d x_{i\mathrm{w}} \sqrt{x_{\tilde{g}\mathrm{w}} x_{i\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{D}^1}^{2\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \Big(F_D^{1b}$$

$$-F_D^{1c} \Big) (x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, 1, x_{\tilde{U}_\alpha^i\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{g}\mathrm{w}})$$

$$+\frac{1}{3\sin\beta} h_d x_{i\mathrm{w}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{D}^1}^{2\delta} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \Big(3F_D^{2a} + 11F_D^{2b}$$

$$+11F_D^{2c} + 2F_D^{2d} - 14F_D^{2e} - 22F_D^{2f} \Big) (x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, 1, x_{\tilde{U}_\alpha^i\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{g}\mathrm{w}})$$

$$+\frac{8}{3\sin\beta} \sqrt{x_{\tilde{g}\mathrm{w}}} x_{i\mathrm{w}} \mathcal{Z}_H^{2j} \mathcal{Z}_{\tilde{D}^3}^{1\gamma} \mathcal{Z}_{\tilde{D}^1}^{2\delta} \mathcal{E}^{ib} \Big(F_A^{1b} - F_A^{1c} \Big) (x_{i\mathrm{w}}, x_{H_j^-\mathrm{w}}, 1, x_{\tilde{U}_\alpha^i\mathrm{w}}, x_{\tilde{D}_\gamma^3\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{g}\mathrm{w}})$$

$$+\frac{1}{\sin\beta} h_d x_{i\mathrm{w}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{D}^1}^{2\delta} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \Big(F_D^{2a} + F_D^{2b} + F_D^{2c} - 2F_D^{2d}$$

$$-2F_D^{2e} - 2F_D^{2f} \Big) (x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, 1, x_{\tilde{U}_\alpha^i\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{g}\mathrm{w}})$$

$$+(i \leftrightarrow j) \ , \tag{94}$$

$$\phi_5^{wh\tilde{g}} = \frac{1}{4} \phi_4^{wh\tilde{g}} \ , \tag{95}$$

$$\phi_6^{wh\tilde{g}} = -\frac{8}{3} h_b h_d \sqrt{x_{\tilde{g}\mathrm{w}} x_{j\mathrm{w}}} (\mathcal{Z}_H^{1k})^2 \Big(\mathcal{Z}_{\tilde{D}^1}^{2\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} + \mathcal{Z}_{\tilde{D}^1}^{2\delta} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \Big) \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \Big(F_D^{1a} - 3F_D^{1b}$$

$$-F_D^{1c} \Big) (x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, 1, x_{\tilde{U}_\alpha^i\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{g}\mathrm{w}})$$

$$+(i \leftrightarrow j) \ , \tag{96}$$

$$\phi_7^{wh\tilde{g}} = \frac{1}{\sin\beta} h_b x_{j\mathrm{w}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \Big(2F_D^{2a} + \frac{14}{3} F_D^{2b} + \frac{14}{3} F_D^{2c} - \frac{4}{3} F_D^{2d}$$

$$-\frac{20}{3} F_D^{2e} - \frac{28}{3} F_D^{2f} \Big) (x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, 1, x_{\tilde{U}_\alpha^i\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{g}\mathrm{w}})$$

$$-\frac{16}{3\sin\beta} h_b \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \sqrt{x_{\tilde{g}\mathrm{w}} x_{i\mathrm{w}}} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \Big(F_D^{1b} - F_D^{1c} \Big) (x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, 1, x_{\tilde{U}_\alpha^i\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{g}\mathrm{w}})$$

$$-\frac{35 h_b \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k}}{3\sin\beta} \frac{x_{\tilde{g}\mathrm{w}}^2 x_{H_k^-\mathrm{w}} x_{j\mathrm{w}} \ln x_{H_k^-\mathrm{w}}}{(x_{\tilde{D}_\delta^1\mathrm{w}} - x_{\tilde{g}\mathrm{w}})(1 - x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}} + x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}} + x_{j\mathrm{w}})}$$

$$-\frac{h_b \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k}}{3\sin\beta} \frac{19 x_{\tilde{g}\mathrm{w}}^2 x_{i\mathrm{w}} x_{j\mathrm{w}} \ln x_{i\mathrm{w}} - 3(x_{\tilde{D}_\delta^1\mathrm{w}} + x_{\tilde{g}\mathrm{w}}) x_{i\mathrm{w}}^2 x_{j\mathrm{w}} \ln x_{i\mathrm{w}}}{(x_{\tilde{D}_\delta^1\mathrm{w}} - x_{\tilde{g}\mathrm{w}})(1 - x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}} - x_{i\mathrm{w}})(-x_{i\mathrm{w}} + x_{j\mathrm{w}})}$$

$$-\frac{h_b \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k}}{3\sin\beta} \frac{19 x_{\tilde{g}\mathrm{w}}^2 x_{j\mathrm{w}}^2 \ln x_{j\mathrm{w}}}{3\sin\beta (x_{\tilde{D}_\delta^1\mathrm{w}} - x_{\tilde{g}\mathrm{w}})(1 - x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}} - x_{j\mathrm{w}})(x_{i\mathrm{w}} - x_{j\mathrm{w}})} \Big)$$

$$+\frac{h_b \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k}}{2\sin\beta} \frac{32 x_{H_k^-\mathrm{w}}^2 x_{j\mathrm{w}} \ln x_{H_k^-\mathrm{w}} + 21 x_{H_k^-\mathrm{w}} x_{\tilde{g}\mathrm{w}} x_{j\mathrm{w}} \ln x_{H_k^-\mathrm{w}}}{(1 - x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}} + x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}} + x_{j\mathrm{w}})}$$

$$+\frac{h_b\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}}{2\sin\beta}\frac{(32x_{i\mathrm{w}}+25x_{\tilde{g}\mathrm{w}})x_{i\mathrm{w}}x_{j\mathrm{w}}\ln x_{i\mathrm{w}}}{(1-x_{i\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{j\mathrm{w}}-x_{i\mathrm{w}})}$$
$$+\frac{h_b\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}}{6\sin\beta}\frac{(166x_{j\mathrm{w}}+39x_{\tilde{g}\mathrm{w}})x_{j\mathrm{w}}^2\ln x_{j\mathrm{w}}}{(1-x_{j\mathrm{w}})(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$
$$-\frac{20h_b\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}}{\sin\beta}\frac{x_{H_k^-\mathrm{w}}x_{j\mathrm{w}}\ln x_{H_k^-\mathrm{w}}}{\sin\beta(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$
$$+\frac{35h_b\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}}{\sin\beta}\frac{x_{i\mathrm{w}}x_{j\mathrm{w}}\ln x_{i\mathrm{w}}}{\sin\beta(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$
$$+\frac{35h_b\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}}{\sin\beta}\frac{x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{\sin\beta(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$
$$+(i\leftrightarrow j)\;, \tag{97}$$

$$\phi_8^{wh\tilde{g}}=\frac{1}{4}\phi_7^{wh\tilde{g}}\;, \tag{98}$$

$$\phi_1^{hh\tilde{g}}=\frac{8}{3\sin^3\beta}x_{i\mathrm{w}}^{\frac{5}{2}}x_{j\mathrm{w}}\mathcal{Z}_H^{2k}(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$+\frac{4}{3\sin^4\beta}x_{i\mathrm{w}}^3x_{j\mathrm{w}}^2(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2(\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2\Big(F_C^{1a}+F_C^{1b}-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$-\frac{16}{3\sin^3\beta}\sqrt{x_{\tilde{g}\mathrm{w}}}x_{i\mathrm{w}}^2x_{j\mathrm{w}}\mathcal{Z}_H^{2k}(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{id}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}F_D^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$-\frac{16}{3\sin^4\beta}x_{i\mathrm{w}}^2\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}x_{j\mathrm{w}}^2(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$+\frac{4}{3\sin^4\beta}x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2(\mathcal{Z}_{\tilde{U}^i}^{2\alpha})^2\Big(F_C^{2a}+F_D^{2d}-F_D^{2e}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$+\frac{4}{3}h_bh_d\mathcal{Z}_H^{1i}\mathcal{Z}_H^{1k}\mathcal{Z}_{\tilde{D}^3}^{1\delta}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{ib}\mathcal{E}^{jd}\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{j\mathrm{w}},x_{H_l^-\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\delta^3\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$+\frac{8}{\sin^3\beta}\mathcal{Z}_H^{2k}(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^{\frac{5}{2}}x_{j\mathrm{w}}\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$
$$-\frac{2}{\sin^4\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\frac{x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}^3x_{j\mathrm{w}}^2\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$
$$+\frac{2}{\sin^4\beta}\left(\frac{(\mathcal{Z}_H^{2k})^2x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}-\frac{(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}^2x_{j\mathrm{w}}^2\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}\right)$$
$$+\frac{8}{\sin^3\beta}\mathcal{Z}_H^{2k}(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{id}\frac{x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^{\frac{5}{2}}x_{j\mathrm{w}}\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{2}{\sin^4\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\frac{x_{H_l^-\mathrm{w}}^2 x_{i\mathrm{w}}^3 x_{j\mathrm{w}}^2\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}$$
$$-\frac{2}{\sin^4\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\frac{x_{H_l^-\mathrm{w}}^3 x_{i\mathrm{w}}^2 x_{j\mathrm{w}}^2\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}$$
$$+\frac{8}{\sin^3\beta}\mathcal{Z}_H^{2k}(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\frac{x_{i\mathrm{w}}^{\frac{7}{2}}x_{j\mathrm{w}}\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$
$$+\frac{2}{\sin^4\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\Big(\frac{x_{i\mathrm{w}}^5 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})^2}$$
$$+\frac{x_{i\mathrm{w}}^4 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}+\frac{x_{i\mathrm{w}}^5 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$
$$+\frac{x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^4 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}\Big)$$
$$+\frac{2}{\sin^4\beta}\Big(\frac{(\mathcal{Z}_H^{2k})^2 x_{i\mathrm{w}}^4 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})^2}+\frac{(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2 x_{i\mathrm{w}}^4 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})^2}$$
$$+\frac{(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2 x_{i\mathrm{w}}^3 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}+\frac{(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2 x_{i\mathrm{w}}^3 x_{j\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}\Big)$$
$$+\frac{8}{\sin^3\beta}\mathcal{Z}_H^{2k}(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\frac{x_{i\mathrm{w}}^{\frac{5}{2}}x_{j\mathrm{w}}^2\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$
$$-\frac{2}{\sin^4\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\frac{(1+x_{i\mathrm{w}})x_{i\mathrm{w}}^2 x_{j\mathrm{w}}^4\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}$$
$$+\frac{2}{\sin^4\beta}(\mathcal{Z}_H^{2k})^2(\mathcal{Z}_H^{2l})^2\frac{x_{i\mathrm{w}}^2 x_{j\mathrm{w}}^4\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}+(i\leftrightarrow j)\;, \tag{99}$$

$$\phi_2^{hh\tilde{g}}=\frac{4}{3\sin\beta}h_bh_d x_{i\mathrm{w}}^{\frac{3}{2}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$-\frac{8}{3\sin^2\beta}h_b\sqrt{x_{\tilde{g}\mathrm{w}}}x_{i\mathrm{w}}x_{j\mathrm{w}}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}$$
$$-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$+\frac{2}{3\sin^2\beta}h_bh_d x_{i\mathrm{w}}^3\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}(\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2\Big(F_C^{1a}+F_C^{1b}-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$
$$+\frac{2}{3\sin^2\beta}h_bh_d x_{j\mathrm{w}}^2\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}(\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2\Big(F_C^{2a}+F_C^{2d}-F_C^{2e}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{8}{3\sin\beta}h_b h_d\sqrt{x_{\tilde{g}\mathrm{w}}}x_{i\mathrm{w}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}$$

$$-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{4}{3\sin^2\beta}h_b x_{i\mathrm{w}}^{\frac{3}{2}}x_{j\mathrm{w}}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{8}{3\sin^2\beta}h_b h_d(x_{i\mathrm{w}}^2+x_{j\mathrm{w}}^2)\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{2}{3\sin^2\beta}h_b h_d x_{i\mathrm{w}}x_{j\mathrm{w}}^2\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}(\mathcal{Z}_{\tilde{U}^i}^{2\alpha})^2\Big(F_C^{1a}+F_C^{1b}-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{2}{3\sin^2\beta}h_b h_d x_{i\mathrm{w}}^2\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}(\mathcal{Z}_{\tilde{U}^i}^{2\alpha})^2\Big(F_C^{2a}+F_C^{2d}-F_C^{2e}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{2}{3\sin^2\beta}x_{j\mathrm{w}}^2\mathcal{Z}_H^{2i}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{1\delta}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{ib}\mathcal{E}^{jd}\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{j\mathrm{w}},x_{H_i^-\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{D}_\delta^3\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{8}{3\sin^2\beta}h_d x_{i\mathrm{w}}x_{j\mathrm{w}}^{\frac{3}{2}}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{16}{3\sin^2\beta}h_b x_{i\mathrm{w}}^2\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}(\mathcal{Z}_H^{2l})^2\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}F_D^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{4}{3\sin^2\beta}h_b h_d(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}((\mathcal{Z}_H^{1l})^2(\mathcal{Z}_H^{2k})^2+(\mathcal{Z}_H^{2l})^2(\mathcal{Z}_H^{1k})^2)(\mathcal{Z}_{\tilde{U}^i}^{1\alpha})^2\Big(F_C^{1a}+F_C^{1b}$$

$$-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{16}{3\sin\beta}h_b h_d x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}}(\mathcal{Z}_H^{1l})^2\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}F_D^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{8}{3\sin\beta}h_b^2 x_{i\mathrm{w}}^{\frac{3}{2}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{8}{3\sin^2\beta}h_b h_d x_{i\mathrm{w}}^{\frac{5}{2}}x_{j\mathrm{w}}^{\frac{3}{2}}((\mathcal{Z}_H^{1l})^2(\mathcal{Z}_H^{2k})^2+(\mathcal{Z}_H^{2l})^2(\mathcal{Z}_H^{1k})^2)\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}$$

$$F_C^0(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{8}{3\sin^2\beta}h_b h_d x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}((\mathcal{Z}_H^{1l})^2(\mathcal{Z}_H^{2k})^2+(\mathcal{Z}_H^{2l})^2(\mathcal{Z}_H^{1k})^2)\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}$$

$$F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{4}{3\sin^2\beta}h_b h_d(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}\Big((\mathcal{Z}_H^{1l})^2(\mathcal{Z}_H^{2k})^2+(\mathcal{Z}_H^{2l})^2(\mathcal{Z}_H^{1k})^2\Big)(\mathcal{Z}_{\tilde{U}^i}^{2\alpha})^2\Big(F_C^{1a}+F_C^{1b}$$

$$-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{8}{3\sin\beta}h_b x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}(\mathcal{Z}_H^{1i}\mathcal{Z}_H^{2k}+\mathcal{Z}_H^{2i}\mathcal{Z}_H^{1k})\mathcal{Z}_{\tilde{D}^3}^{2\delta}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{ib}\mathcal{E}^{jd}$$

$$F_A^0(x_{j\mathrm{w}},x_{H_i^-\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_m^1\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-\frac{4}{3\sin\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{id}\frac{x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^2(\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\sqrt{x_{i\mathrm{w}}}-2\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\sqrt{x_{\tilde{g}\mathrm{w}}})\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{4}{3\sin^2\beta}h_b \mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{E}^{id}\frac{(2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\sqrt{x_{\tilde{g}\mathrm{w}}}-\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\sqrt{x_{i\mathrm{w}}})x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{1}{3\sin^2\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\frac{(x_{i\mathrm{w}}^2+x_{j\mathrm{w}}^2)(x_{H_k^-\mathrm{w}}^2 x_{i\mathrm{w}}+x_{H_k^-\mathrm{w}}^3)\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{1}{3\sin^2\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\frac{x_{H_k^-\mathrm{w}}^2 x_{i\mathrm{w}}^2\ln(x_{H_k^-\mathrm{w}})}{(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{4}{3\sin\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{id}\frac{(\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\sqrt{x_{i\mathrm{w}}}-2\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\sqrt{x_{\tilde{g}\mathrm{w}}})x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{4}{3\sin^2\beta}h_b \mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{E}^{id}\frac{(2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\sqrt{x_{\tilde{g}\mathrm{w}}}-\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\sqrt{x_{i\mathrm{w}}})x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{1}{3\sin^2\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\frac{(x_{i\mathrm{w}}^2+x_{j\mathrm{w}}^2)(x_{H_l^-\mathrm{w}}^2 x_{i\mathrm{w}}+x_{H_l^-\mathrm{w}}^3)\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{4}{3\sin\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{id}\frac{(\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\sqrt{x_{i\mathrm{w}}}-2\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\sqrt{x_{\tilde{g}\mathrm{w}}})x_{i\mathrm{w}}^2\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$

$$+\frac{8}{3\sin^2\beta}h_b \mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\frac{\sqrt{x_{\tilde{g}\mathrm{w}}}x_{i\mathrm{w}}^2 x_{j\mathrm{w}}\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{1}{3\sin^2\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\Big(3x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^5-x_{j\mathrm{w}}^5(x_{i\mathrm{w}}^2+x_{j\mathrm{w}}^2)-5x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^4x_{j\mathrm{w}}$$

$$+3(x_{H_k^-\mathrm{w}}+x_{H_k^-\mathrm{w}})x_{i\mathrm{w}}^5x_{j\mathrm{w}}+3x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}^2-(x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})x_{i\mathrm{w}}^4(x_{i\mathrm{w}}^2+x_{j\mathrm{w}}^2)$$

$$-5x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^2x_{j\mathrm{w}}^3+3x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}^3+3x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}^3-x_{i\mathrm{w}}^4x_{j\mathrm{w}}(x_{i\mathrm{w}}^2+x_{j\mathrm{w}}^2)\Big)$$

$$\frac{\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})^2(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})^2(-x_{i\mathrm{w}}+x_{j\mathrm{w}})^2}$$

$$-\frac{4}{3\sin^2\beta}h_b \mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{E}^{id}\frac{(\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\sqrt{x_{i\mathrm{w}}}-2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\sqrt{x_{\tilde{g}\mathrm{w}}})x_{i\mathrm{w}}^2x_{j\mathrm{w}}\ln x_{i\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}$$

$$-\frac{4}{3\sin\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{id}\frac{(\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\sqrt{x_{i\mathrm{w}}}-2\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\sqrt{x_{\tilde{g}\mathrm{w}}})x_{i\mathrm{w}}x_{j\mathrm{w}}\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$-\frac{4}{3\sin^2\beta}h_b \mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\frac{x_{i\mathrm{w}}^{\frac{3}{2}}x_{j\mathrm{w}}^2\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}$$

$$+\frac{1}{3\sin^2\beta}h_b h_d \mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\frac{(x_{i\mathrm{w}}^3+x_{i\mathrm{w}}^2x_{j\mathrm{w}}+x_{i\mathrm{w}}x_{j\mathrm{w}}^2+x_{j\mathrm{w}}^3)x_{j\mathrm{w}}^2\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}$$
$$+(i\leftrightarrow j)\;, \tag{100}$$

$$\phi_3^{hh\tilde g}=-2\phi_2^{hh\tilde g}\;, \tag{101}$$

$$\phi_4^{hh\tilde g}=-\frac{16}{3\sin^2\beta}h_d(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac32}\sqrt{x_{\tilde g\mathrm{w}}}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde D^1}^{2\gamma}\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{E}^{id}F_D^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde D_\gamma^1\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$+\frac{4}{3\sin^2\beta}h_d^2(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac32}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\Big((\mathcal{Z}_{\tilde U^i}^{1\alpha})^2+(\mathcal{Z}_{\tilde U^i}^{2\alpha})^2\Big)\Big(F_C^{1a}+F_C^{1b}$$
$$-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$-\frac{8}{3\sin^2\beta}h_d^2x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde g\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_{\tilde U^i}^{2\alpha}F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$+\frac{8}{3\sin^2\beta}h_dx_{i\mathrm{w}}x_{j\mathrm{w}}^{\frac32}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde D^1}^{2\gamma}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde D_\gamma^1\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$-\frac{8}{3\sin^2\beta}h_d^2x_{i\mathrm{w}}^{\frac52}x_{j\mathrm{w}}^{\frac32}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_{\tilde U^i}^{2\alpha}F_C^0(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$-\frac{8}{3\sin\beta}h_bx_{j\mathrm{w}}^{\frac32}\sqrt{x_{\tilde g\mathrm{w}}}\mathcal{Z}_H^{1i}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde D^3}^{1\delta}\mathcal{Z}_{\tilde D^1}^{2\gamma}\mathcal{E}^{ib}\mathcal{E}^{jd}F_A^0(x_{j\mathrm{w}},x_{H_i^-\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde D_m^1\mathrm{w}},x_{\tilde D_\gamma^1\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$+(i\leftrightarrow j)\;, \tag{102}$$

$$\phi_5^{hh\tilde g}=\frac14\phi_4^{hh\tilde g}\;, \tag{103}$$

$$\phi_6^{hh\tilde g}=-\frac{16}{3}h_b^2h_d\sqrt{x_{\tilde g\mathrm{w}}}\mathcal{Z}_H^{1k}(\mathcal{Z}_H^{1l})^2\mathcal{Z}_{\tilde D^1}^{2\gamma}\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{E}^{id}F_D^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde D_\gamma^1\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$-\frac{16}{3}h_b^2h_d^2\sqrt{x_{\tilde g\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_{\tilde U^i}^{2\alpha}F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$+\frac43h_b^2h_d^2(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2(\mathcal{Z}_{\tilde U^i}^{1\alpha})^2\Big(F_C^{2a}+F_C^{2d}-F_C^{2e}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$+\frac83h_b^2h_d\sqrt{x_{i\mathrm{w}}}\mathcal{Z}_H^{1k}(\mathcal{Z}_H^{1l})^2\mathcal{Z}_{\tilde D^1}^{2\gamma}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde D_\gamma^1\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$+\frac43h_b^2h_d^2x_{i\mathrm{w}}(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2(\mathcal{Z}_{\tilde U^i}^{2\alpha})^2\Big(F_C^{1a}+F_C^{1b}-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$+\frac{4}{3\sin^2\beta}x_{j\mathrm{w}}^2\mathcal{Z}_H^{2i}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde D^3}^{2\delta}\mathcal{Z}_{\tilde D^1}^{2\gamma}\mathcal{E}^{ib}\mathcal{E}^{jd}\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{j\mathrm{w}},x_{H_i^-\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}},x_{\tilde D_m^1\mathrm{w}},x_{\tilde D_\gamma^1\mathrm{w}},x_{\tilde g\mathrm{w}})$$
$$-2h_b^2h_d^2(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2\frac{x_{H_k^-\mathrm{w}}^3\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}$$

$$
\begin{aligned}
&-2h_b^2h_d^2(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2\frac{x_{H_l^-\mathrm{w}}^3\ln x_{H_l^-\mathrm{w}}}{(-x_{H_l^-\mathrm{w}}+x_{H_k^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}\\
&-2h_b^2h_d^2(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2\frac{x_{H_k^-\mathrm{w}}^2x_{i\mathrm{w}}\ln x_{H_k^-\mathrm{w}}}{(-x_{H_k^-\mathrm{w}}+x_{H_l^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}\\
&-2h_b^2h_d^2(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2\frac{x_{H_l^-\mathrm{w}}^2x_{i\mathrm{w}}\ln x_{H_l^-\mathrm{w}}}{(-x_{H_l^-\mathrm{w}}+x_{H_k^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}\\
&+2h_b^2h_d^2(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2\Big(-3x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^3+x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^4+x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^4\\
&+x_{i\mathrm{w}}^5+5x_{H_k^-\mathrm{w}}x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^2x_{j\mathrm{w}}-3x_{H_k^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}-3x_{H_l^-\mathrm{w}}x_{i\mathrm{w}}^3x_{j\mathrm{w}}+x_{i\mathrm{w}}^4x_{j\mathrm{w}}\Big)\\
&\frac{\ln x_{H_k^-\mathrm{w}}}{(-x_{H_l^-\mathrm{w}}+x_{H_k^-\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})^2(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})^2}\\
&-2h_b^2h_d^2(\mathcal{Z}_H^{1k})^2(\mathcal{Z}_H^{1l})^2\frac{(x_{i\mathrm{w}}x_{j\mathrm{w}}^2+x_{j\mathrm{w}}^3)\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})^2}\\
&+8h_b^2h_d\mathcal{Z}_H^{1k}(\mathcal{Z}_H^{1l})^2\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\frac{x_{H_l^-\mathrm{w}}\sqrt{x_{i\mathrm{w}}}\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{H_l^-\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{j\mathrm{w}})}\\
&+8h_b^2h_d\mathcal{Z}_H^{1k}(\mathcal{Z}_H^{1l})^2\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\frac{x_{H_k^-\mathrm{w}}\sqrt{x_{i\mathrm{w}}}\ln x_{H_k^-\mathrm{w}}}{(x_{H_l^-\mathrm{w}}-x_{H_k^-\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{H_k^-\mathrm{w}}+x_{j\mathrm{w}})}\\
&+8h_b^2h_d\mathcal{Z}_H^{1k}(\mathcal{Z}_H^{1l})^2\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\frac{x_{i\mathrm{w}}^{\frac{3}{2}}\ln x_{H_l^-\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{H_l^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{j\mathrm{w}})}\\
&+8h_b^2h_d\mathcal{Z}_H^{1k}(\mathcal{Z}_H^{1l})^2\mathcal{Z}_{\tilde{D}^1}^{2\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}\frac{\sqrt{x_{i\mathrm{w}}}x_{j\mathrm{w}}\ln x_{j\mathrm{w}}}{(x_{H_k^-\mathrm{w}}-x_{j\mathrm{w}})(x_{H_l^-\mathrm{w}}-x_{j\mathrm{w}})(x_{i\mathrm{w}}-x_{j\mathrm{w}})}\\
&+(i\leftrightarrow j)\ , \qquad (104)
\end{aligned}
$$

$$
\begin{aligned}
\phi_7^{hh\tilde{g}}=&\frac{8}{3\sin\beta}h_b^2x_{i\mathrm{w}}\sqrt{x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{E}^{id}\Big(F_D^{1a}+F_D^{1b}-F_D^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})\\
&+\frac{4}{3\sin^2\beta}h_b^2(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\Big(F_C^{1a}+F_C^{1b}-F_C^{1c}\Big)(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})\\
&-\frac{8}{3\sin^2\beta}h_b^2x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}F_C^{1a}(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})\\
&-\frac{16}{3\sin\beta}h_b^2x_{i\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{E}^{id}F_D^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})\\
&-\frac{8}{3\sin^2\beta}h_b^2x_{i\mathrm{w}}^{\frac{5}{2}}x_{j\mathrm{w}}^{\frac{3}{2}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{1l}\mathcal{Z}_H^{2k}\mathcal{Z}_H^{2l}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}F_C^0(x_{j\mathrm{w}},x_{i\mathrm{w}},x_{i\mathrm{w}},x_{H_k^-\mathrm{w}},x_{H_l^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{g}\mathrm{w}})
\end{aligned}
$$

$$-\frac{8}{3\sin\beta}h_d x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2i}\mathcal{Z}_{\tilde{D}^3}^{2\delta}\mathcal{Z}_{\tilde{D}^1}^{1\gamma}\mathcal{E}^{ib}\mathcal{E}^{jd}F_A^0(x_{j\mathrm{w}},x_{H_i^-\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\tilde{D}_m^1\mathrm{w}},x_{\tilde{D}_\gamma^1\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+(i\leftrightarrow j)\ , \tag{105}$$

$$\phi_8^{hh\tilde{g}}=\frac{1}{4}\phi_7^{hh\tilde{g}}\ , \tag{106}$$

$$\begin{aligned}
\phi_1^{sw\tilde{g}}=&\frac{4}{3}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_{\tilde{D}^3}^{1m}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\\
&\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},1,x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_l^1\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}})\\
&+\frac{4}{3}x_{i\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\\
&\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},1,x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_l^1\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}})\\
&-\frac{4}{3}x_{i\mathrm{w}}x_{j\mathrm{w}}\Big(\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}+\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\Big)\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\\
&\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},1,x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_l^1\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}})\\
&+\frac{4}{3}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\\
&\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},1,x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})\\
&+\frac{4}{3}\Big(\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}+\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\Big)\\
&\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\\
&\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},1,x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})\\
&-\frac{4}{3}\sqrt{x_{i\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\\
&\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},1,x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})\\
&+(i\leftrightarrow j)\ ,
\end{aligned} \tag{107}$$

$$\begin{aligned}
\phi_2^{sw\tilde{g}}=&\frac{2}{3}\Big(\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\\
&+\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2l}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2l}}{\sqrt{2}}\Big)
\end{aligned}$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\rm w},x_{j\rm w},1,x_{\kappa_\eta^-{\rm w}},x_{\tilde g{\rm w}},x_{\tilde D_l^1{\rm w}},x_{\tilde D_m^3{\rm w}})$$

$$+\frac{2}{3}\Big(\sqrt{x_{\tilde g{\rm w}}x_{i\rm w}}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_{\tilde U^j}^{1\beta}+\sqrt{x_{\tilde g{\rm w}}x_{j\rm w}}\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_{\tilde U^j}^{2\beta}\Big)\frac{h_b\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2l}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_-^{2l}}{\sqrt{2}}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\rm w},x_{j\rm w},1,x_{\tilde g{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{\tilde U_\beta^j{\rm w}},x_{\tilde U_\alpha^i{\rm w}})$$

$$-\frac{2}{3}\sqrt{x_{i\rm w}x_{j\rm w}}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_{\tilde U^j}^{2\beta}\frac{h_b\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2l}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_-^{2l}}{\sqrt{2}}$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\rm w},x_{j\rm w},1,x_{\tilde g{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{\tilde U_\beta^j{\rm w}},x_{\tilde U_\alpha^i{\rm w}})$$

$$+\frac{2}{3}x_{i\rm w}\sqrt{x_{\kappa_\eta^-{\rm w}}x_{i\rm w}}\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_{\tilde D^1}^{2\delta}\Big(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\rm w},x_{j\rm w},1,x_{\kappa_\eta^-{\rm w}},x_{\tilde g{\rm w}},x_{\tilde D_l^1{\rm w}},x_{\tilde D_m^3{\rm w}})$$

$$-\frac{2}{3}x_{i\rm w}x_{j\rm w}\Big(\sqrt{x_{\kappa_\eta^-{\rm w}}x_{j\rm w}}+\sqrt{x_{i\rm w}x_{j\rm w}}\Big)\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_{\tilde D^1}^{2\delta}\frac{\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\frac{\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\rm w},x_{j\rm w},1,x_{\kappa_\eta^-{\rm w}},x_{\tilde g{\rm w}},x_{\tilde D_l^1{\rm w}},x_{\tilde D_m^3{\rm w}})$$

$$+(i\leftrightarrow j)\;, \tag{108}$$

$$\phi_3^{sw\tilde g}=-2\phi_2^{sw\tilde g}\;, \tag{109}$$

$$\phi_1^{sh\tilde g}=\frac{2}{3\sin^2\beta}x_{i\rm w}x_{j\rm w}\sqrt{x_{i\rm w}x_{j\rm w}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\Big(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\rm w},x_{j\rm w},x_{H_k^-{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{\tilde g{\rm w}},x_{\tilde D_\delta^1{\rm w}},x_{\tilde D_\gamma^3{\rm w}})$$

$$+\frac{2}{3\sin^2\beta}x_{i\rm w}x_{j\rm w}\sqrt{x_{\kappa_\eta^-{\rm w}}x_{j\rm w}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\Big(-\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}-\frac{h_d\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{x_{i\rm w}\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\rm w},x_{j\rm w},x_{H_k^-{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{\tilde g{\rm w}},x_{\tilde D_\delta^1{\rm w}},x_{\tilde D_\gamma^3{\rm w}})$$

$$+\frac{2}{3\sin^2\beta}x_{i\rm w}\sqrt{x_{\kappa_\eta^-{\rm w}}x_{i\rm w}}x_{j\rm w}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\Big(-\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}-\frac{h_b\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{x_{j\rm w}\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\rm w},x_{j\rm w},x_{H_k^-{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{\tilde g{\rm w}},x_{\tilde D_\delta^1{\rm w}},x_{\tilde D_\gamma^3{\rm w}})$$

$$-\frac{2}{3\sin^2\beta}x_{i\rm w}x_{j\rm w}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\frac{x_{i\rm w}\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\frac{x_{j\rm w}\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\rm w},x_{j\rm w},x_{H_k^-{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{\tilde g{\rm w}},x_{\tilde D_\delta^1{\rm w}},x_{\tilde D_\gamma^3{\rm w}})$$

$$-\frac{2}{3\sin^2\beta}x_{i\rm w}x_{j\rm w}\sqrt{x_{i\rm w}x_{j\rm w}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_{\tilde U^j}^{1\beta}\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{2}{3\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{2}{3\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{2}{3\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+(i\leftrightarrow j)\;, \tag{110}$$

$$\phi_2^{sh\tilde{g}}=-\frac{1}{3}h_bh_d(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{2}{3\sin\beta}h_dx_{i\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{4}{3\sin\beta}h_bx_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta})+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$+\frac{1}{3\sin^2\beta}(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{1}{3\sin^2\beta}(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{1}{2\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{2k})^2\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{1}{3\sin^2\beta}(x_{i\mathrm{w}}x_{j\mathrm{w}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$-\frac{1}{3}h_bh_d\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{x_{i\mathrm{w}}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$+\frac{2}{3\sin\beta}h_d\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}}x_{i\mathrm{w}}^2\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$F_A^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$+\frac{4}{3\sin\beta}h_bx_{j\mathrm{w}}x_{i\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$F_A^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{1}{3\sin^2\beta}x_{i\mathrm{w}}^2x_{j\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{1}{3}h_bh_dx_{j\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$+\frac{4}{3\sin\beta}h_dx_{i\mathrm{w}}x_{j\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$F_A^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$+\frac{2}{3\sin\beta}h_bx_{j\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}}x_{j\mathrm{w}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$F_A^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{1}{3\sin^2\beta}x_{i\mathrm{w}}x_{j\mathrm{w}}^2\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{2k})^2\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\left(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\right)\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$+\frac{1}{3}h_bh_d(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a} - F_A^{1b} - F_A^{1c}\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{4}{3\sin\beta} h_d x_{i\mathrm{w}}^2 x_{j\mathrm{w}} \sqrt{x_{\tilde{g}\mathrm{w}} x_{j\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{D}^3}^{2\gamma} \mathcal{Z}_{\tilde{D}^1}^{1\delta} \frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma} \mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta} \frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a} - F_A^{1b} + F_A^{1c}\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{2}{3\sin\beta} h_b x_{i\mathrm{w}} x_{j\mathrm{w}}^2 \sqrt{x_{\tilde{g}\mathrm{w}} x_{i\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{D}^3}^{1\gamma} \mathcal{Z}_{\tilde{D}^1}^{2\delta} \frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma} \mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta} \frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a} - F_A^{1b} + F_A^{1c}\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{1}{3\sin^2\beta} x_{i\mathrm{w}}^2 x_{j\mathrm{w}}^2 (\mathcal{Z}_H^{2k})^2 \mathcal{Z}_{\tilde{D}^3}^{2\gamma} \mathcal{Z}_{\tilde{D}^1}^{2\delta} \frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma} \mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta} \frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta} \mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{2b} + F_A^{2c} - F_A^{2d} - F_A^{2e} - 2F_A^{2f}\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\tilde{D}_\delta^1\mathrm{w}}, x_{\tilde{D}_\gamma^3\mathrm{w}})$$

$$-\frac{2}{3\sin\beta} h_b x_{i\mathrm{w}} \sqrt{x_{\kappa_\eta^-\mathrm{w}} x_{i\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \frac{h_d \mathcal{Z}_{\tilde{U}^j}^{1\beta} \mathcal{Z}_-^{2\eta}}{\sqrt{2}} \Big(- \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_+^{1\eta} + \frac{m_{u^i} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_+^{2\eta}}{\sqrt{2} m_\mathrm{w} \sin\beta}\Big)$$

$$\Big(F_A^{1a} - F_A^{1b} + F_A^{1c}\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{U}_\beta^j\mathrm{w}}, x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{4}{3\sin\beta} h_b x_{i\mathrm{w}} \sqrt{x_{\tilde{g}\mathrm{w}} x_{j\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \frac{h_d \mathcal{Z}_{\tilde{U}^j}^{1\beta} \mathcal{Z}_-^{2\eta}}{\sqrt{2}} \Big(- \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_+^{1\eta} + \frac{m_{u^i} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_+^{2\eta}}{\sqrt{2} m_\mathrm{w} \sin\beta}\Big)$$

$$F_A^{1a}(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{U}_\beta^j\mathrm{w}}, x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{4}{3\sin\beta} h_b x_{i\mathrm{w}} \sqrt{x_{\kappa_i^-\mathrm{w}} x_{\kappa_\eta^-\mathrm{w}} x_{\tilde{g}\mathrm{w}} x_{j\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{U}^j}^{2\beta} \frac{h_d \mathcal{Z}_{\tilde{U}^j}^{1\beta} \mathcal{Z}_-^{2\eta}}{\sqrt{2}} \Big(- \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_+^{1\eta} + \frac{m_{u^i} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_+^{2\eta}}{\sqrt{2} m_\mathrm{w} \sin\beta}\Big)$$

$$F_A^{0}(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{U}_\beta^j\mathrm{w}}, x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$-\frac{2}{3\sin\beta} h_b x_{i\mathrm{w}} \sqrt{x_{\kappa_\eta^-\mathrm{w}} x_{j\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_{\tilde{U}^j}^{2\beta} \frac{h_d \mathcal{Z}_{\tilde{U}^j}^{1\beta} \mathcal{Z}_-^{2\eta}}{\sqrt{2}} \Big(- \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_+^{1\eta} + \frac{m_{u^i} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_+^{2\eta}}{\sqrt{2} m_\mathrm{w} \sin\beta}\Big)$$

$$\Big(F_A^{1a} - F_A^{1b} + F_A^{1c}\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{U}_\beta^j\mathrm{w}}, x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$-\frac{2}{3\sin\beta} h_d x_{j\mathrm{w}} \sqrt{x_{\kappa_\eta^-\mathrm{w}} x_{j\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \frac{h_b \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_-^{2\eta}}{\sqrt{2}} \Big(- \mathcal{Z}_{\tilde{U}^j}^{1\beta} \mathcal{Z}_+^{1\eta} + \frac{m_{u^j} \mathcal{Z}_{\tilde{U}^j}^{2\beta} \mathcal{Z}_+^{2\eta}}{\sqrt{2} m_\mathrm{w} \sin\beta}\Big)$$

$$\Big(F_A^{1a} - F_A^{1b} + F_A^{1c}\Big)(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{U}_\beta^j\mathrm{w}}, x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$+\frac{4}{3\sin\beta} h_d x_{j\mathrm{w}} \sqrt{x_{\kappa_i^-\mathrm{w}} x_{\kappa_\eta^-\mathrm{w}} x_{\tilde{g}\mathrm{w}} x_{l\mathrm{w}}} \mathcal{Z}_H^{1k} \mathcal{Z}_H^{2k} \mathcal{Z}_{\tilde{U}^i}^{2\alpha} \mathcal{Z}_{\tilde{U}^j}^{1\beta} \frac{h_b \mathcal{Z}_{\tilde{U}^i}^{1\alpha} \mathcal{Z}_-^{2\eta}}{\sqrt{2}} \Big(- \mathcal{Z}_{\tilde{U}^j}^{1\beta} \mathcal{Z}_+^{1\eta} + \frac{m_{u^j} \mathcal{Z}_{\tilde{U}^j}^{2\beta} \mathcal{Z}_+^{2\eta}}{\sqrt{2} m_\mathrm{w} \sin\beta}\Big)$$

$$F_A^{0}(x_{i\mathrm{w}}, x_{j\mathrm{w}}, x_{H_k^-\mathrm{w}}, x_{\tilde{g}\mathrm{w}}, x_{\kappa_\eta^-\mathrm{w}}, x_{\tilde{U}_\beta^j\mathrm{w}}, x_{\tilde{U}_\alpha^i\mathrm{w}})$$

$$
\begin{aligned}
&+\frac{4}{3\sin\beta}h_d x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{l\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\\
&F_A^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})\\
&-\frac{2}{3\sin\beta}h_d\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{i\mathrm{w}}}x_{j\mathrm{w}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\\
&\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})\\
&+\frac{1}{3}h_bh_d(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\\
&\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})\\
&+\frac{1}{3}h_bh_d\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{1k})^2\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}-\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\Big)\\
&\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\\
&\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})\\
&+(i\leftrightarrow j)\;,
\end{aligned}
\tag{111}
$$

$$
\phi_3^{sh\tilde{g}}=-2\phi_2^{sh\tilde{g}}\;,
\tag{112}
$$

$$
\begin{aligned}
\phi_4^{sh\tilde{g}}=&\frac{2}{3\sin\beta}h_d x_{i\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\\
&\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})\\
&-\frac{2}{3\sin\beta}h_d x_{i\mathrm{w}}^2\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\\
&F_A^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})\\
&-\frac{4}{3\sin\beta}h_d(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\\
&F_A^{0}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})\\
&+\frac{4}{3\sin\beta}h_d x_{i\mathrm{w}}^2x_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\\
&\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})
\end{aligned}
$$

$$+\frac{2}{3\sin\beta}h_dx_{j\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$
$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$
$$-\frac{4}{3\sin\beta}h_dx_{j\mathrm{w}}\sqrt{x_{\kappa_i^-\mathrm{w}}x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}x_{l\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$
$$F_A^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$
$$-\frac{4}{3\sin\beta}h_dx_{j\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{l\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$
$$F_A^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$
$$+\frac{2}{3\sin\beta}h_d\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{i\mathrm{w}}}x_{j\mathrm{w}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$
$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$
$$+(i\leftrightarrow j)\;, \tag{113}$$

$$\phi_5^{sh\tilde{g}}=\frac{1}{4}\phi_4^{sh\tilde{g}}\;, \tag{114}$$

$$\phi_6^{sh\tilde{g}}=-\frac{2}{3}h_bh_d(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$
$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$
$$+\frac{2}{3}h_bh_d(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$
$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$
$$+\frac{2}{3}h_bh_d\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{1k})^2\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{1\beta}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}-\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$
$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{U}_\alpha^i\mathrm{w}})$$
$$-\frac{2}{3}h_bh_dx_{i\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{i\mathrm{w}}}(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$
$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_\delta^1\mathrm{w}},x_{\tilde{D}_\gamma^3\mathrm{w}})$$
$$-\frac{2}{3}h_bh_dx_{j\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_{\tilde{D}^1}^{2\delta}\Big(\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D_\delta^1\mathrm{w}},x_{\tilde D_\gamma^3\mathrm{w}})$$

$$+\frac{2}{3}h_bh_d(x_{i\mathrm{w}}x_{j\mathrm{w}})^{\frac{3}{2}}(\mathcal{Z}_H^{1k})^2\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_{\tilde D^1}^{2\delta}\frac{\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\frac{\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D_\delta^1\mathrm{w}},x_{\tilde D_\gamma^3\mathrm{w}})$$

$$+(i\leftrightarrow j)\;, \tag{115}$$

$$\phi_7^{sh\tilde g}=\frac{4}{3\sin\beta}h_bx_{j\mathrm{w}}\sqrt{x_{\tilde g\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\Big(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D_\delta^1\mathrm{w}},x_{\tilde D_\gamma^3\mathrm{w}})$$

$$-\frac{4}{3\sin\beta}h_b(x_{i\mathrm{w}}x_{j\mathrm{w}})^2\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde g\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\Big(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$F_A^0(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D_\delta^1\mathrm{w}},x_{\tilde D_\gamma^3\mathrm{w}})$$

$$-\frac{2}{3\sin\beta}h_bx_{j\mathrm{w}}^2\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde g\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\Big(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_b\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$F_A^{1a}(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D_\delta^1\mathrm{w}},x_{\tilde D_\gamma^3\mathrm{w}})$$

$$+\frac{2}{3\sin\beta}h_bx_{i\mathrm{w}}x_{j\mathrm{w}}^2\sqrt{x_{\tilde g\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\frac{\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}\frac{\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}\sin\beta}$$

$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D_\delta^1\mathrm{w}},x_{\tilde D_\gamma^3\mathrm{w}})$$

$$+\frac{2}{3\sin\beta}h_bx_{i\mathrm{w}}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{i\mathrm{w}}}\mathcal{Z}_H^{1k}\mathcal{Z}_H^{2k}\Big(\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_{\tilde U^j}^{1\beta}-2\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_{\tilde U^j}^{1\beta}+\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_{\tilde U^j}^{2\beta}\Big)$$

$$\frac{h_b\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{i\mathrm{w}},x_{j\mathrm{w}},x_{H_k^-\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde U_\beta^j\mathrm{w}},x_{\tilde U_\alpha^i\mathrm{w}})$$

$$+(i\leftrightarrow j)\;, \tag{116}$$

$$\phi_8^{sh\tilde g}=\frac{1}{4}\phi_7^{sh\tilde g}\;, \tag{117}$$

$$\phi_1^{p\tilde g}=-\frac{16}{3}\Bigg(\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_{\tilde D^1}^{1\delta}\Big(-\mathcal{Z}_{\tilde D^3}^{1\gamma}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde D^3}^{2\gamma}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big)\Big(-(\mathcal{Z}_{\tilde D^1}^{1\delta}\mathcal{Z}_-^{1\eta})+\frac{(h_d\mathcal{Z}_{\tilde D^1}^{2\delta}\mathcal{Z}_-^{2\eta})}{\sqrt{2}}\Big)$$

$$\Big(-(\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\lambda})+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)\Bigg)$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}^3_\gamma\mathrm{w}},x_{\tilde{D}^1_\delta\mathrm{w}})$$

$$+\frac{16}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\Big(-\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2\delta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}^3_\gamma\mathrm{w}},x_{\tilde{D}^1_\delta\mathrm{w}})$$

$$+\frac{16}{3}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\Big(-\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde{D}^3}^{2\gamma}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda})}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}^3_\gamma\mathrm{w}},x_{\tilde{D}^1_\delta\mathrm{w}})$$

$$+\frac{16}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{\kappa_\eta^-\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1\gamma}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big(-(\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda})+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1\delta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big(-(\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta})+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}^3_\gamma\mathrm{w}},x_{\tilde{D}^1_\delta\mathrm{w}})$$

$$-\frac{64}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\Big(-(\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda})+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}$$

$$+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$F_C^{1a}(x_{\tilde{U}^i_{\alpha_1}\mathrm{w}},x_{\kappa_\lambda^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}^j_\beta\mathrm{w}},x_{i\mathrm{w}},x_{\tilde{U}^i_{\alpha_2}\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$-32x_{\kappa_\lambda^-\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^m}^{1n}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^m}^{2n}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^i_\alpha\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^j_\beta\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^i_\alpha\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^j_\beta\mathrm{w}})}\Big)$$

$$-32x_{\kappa_\eta^-\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(-(\mathcal{Z}_{\tilde U^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda})+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\kappa_\eta^-{\rm w}}}{(x_{\kappa_\lambda^-{\rm w}}-x_{\kappa_\eta^-{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{\tilde U_\alpha^i{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{\tilde U_\beta^j{\rm w}})}$$

$$-\frac{x_{i{\rm w}}\ln x_{\kappa_\eta^-{\rm w}}}{(x_{\kappa_\lambda^-{\rm w}}-x_{\kappa_\eta^-{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{i{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{\tilde U_\alpha^i{\rm w}})(-x_{\kappa_\eta^-{\rm w}}+x_{\tilde U_\beta^j{\rm w}})}\Big)$$

$$+32x_{i{\rm w}}^2\sqrt{x_{\tilde g{\rm w}}x_{i{\rm w}}}\Big(\mathcal{Z}_{\tilde U^i}^{2\alpha_1}\mathcal{Z}_{\tilde U^m}^{1n}+\mathcal{Z}_{\tilde U^i}^{1\alpha_1}\mathcal{Z}_{\tilde U^i}^{2\alpha_2}\Big)\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\frac{\ln x_{i{\rm w}}}{(x_{\kappa_\lambda^-{\rm w}}-x_{i{\rm w}})(x_{\kappa_\eta^-{\rm w}}-x_{i{\rm w}})(-x_{i{\rm w}}+x_{\tilde U_\alpha^i{\rm w}})(-x_{i{\rm w}}+x_{\tilde U_\beta^j{\rm w}})}$$

$$-32(\sqrt{x_{\tilde g{\rm w}}x_{i{\rm w}}}x_{\tilde U_\alpha^i{\rm w}}\Big(\mathcal{Z}_{\tilde U^i}^{2\alpha_1}\mathcal{Z}_{\tilde U^i}^{1\alpha_2}+\mathcal{Z}_{\tilde U^i}^{1\alpha_1}\mathcal{Z}_{\tilde U^i}^{2\alpha_2}\Big)\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\tilde U_\alpha^i{\rm w}}}{(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde U_\alpha^i{\rm w}})(x_{\kappa_\eta^-{\rm w}}-x_{\tilde U_\alpha^i{\rm w}})(-x_{\tilde U_\alpha^i{\rm w}}+x_{\tilde U_\beta^j{\rm w}})}$$

$$-\frac{x_{i{\rm w}}\ln x_{\tilde U_\alpha^i{\rm w}}}{(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde U_\alpha^i{\rm w}})(x_{\kappa_\eta^-{\rm w}}-x_{\tilde U_\alpha^i{\rm w}})(x_{i{\rm w}}-x_{\tilde U_\alpha^i{\rm w}})(-x_{\tilde U_\alpha^i{\rm w}}+x_{\tilde U_\beta^j{\rm w}})}\Big)$$

$$-32\sqrt{x_{\tilde g{\rm w}}x_{i{\rm w}}}x_{\tilde U_\beta^j{\rm w}}\Big(\mathcal{Z}_{\tilde U^i}^{2\alpha_1}\mathcal{Z}_{\tilde U^i}^{1\alpha_2}+\mathcal{Z}_{\tilde U^m}^{1i}\mathcal{Z}_{\tilde U^i}^{2\alpha_2}\Big)\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)$$

$$\Big(-\mathcal{Z}_{\tilde U^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\Big(\frac{\ln x_{\tilde U_\beta^j{\rm w}}}{(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde U_\beta^j{\rm w}})(x_{\kappa_\eta^-{\rm w}}-x_{\tilde U_\beta^j{\rm w}})(x_{\tilde U_\alpha^i{\rm w}}-x_{\tilde U_\beta^j{\rm w}})}$$

$$-\frac{x_{i{\rm w}}\ln x_{\tilde U_\beta^j{\rm w}}}{(x_{\kappa_\lambda^-{\rm w}}-x_{\tilde U_\beta^j{\rm w}})(x_{\kappa_\eta^-{\rm w}}-x_{\tilde U_\beta^j{\rm w}})(x_{i{\rm w}}-x_{\tilde U_\beta^j{\rm w}})(x_{\tilde U_\alpha^i{\rm w}}-x_{\tilde U_\beta^j{\rm w}})}\Big)+(i\leftrightarrow j)\;, \tag{118}$$

$$\phi_2^{p\tilde g}=8\sqrt{x_{\kappa_\lambda^-{\rm w}}x_{\kappa_\eta^-{\rm w}}}\mathcal{Z}_{\tilde D^3}^{1n}\mathcal{Z}_{\tilde D^1}^{1m}\frac{h_d\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde D^3}^{2m}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big)$$

$$\frac{h_b\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$+\frac{8}{3}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde D^3}^{1n}\mathcal{Z}_{\tilde D^1}^{1m}\frac{h_d\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\lambda}}{\sqrt2}\frac{h_b\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt2}\Big(-\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt2}\Big)\frac{m_{u^j}\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$+\frac{8}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde D^3}^{1n}\mathcal{Z}_{\tilde D^1}^{1m}\frac{h_d\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\lambda}}{\sqrt2}\Big(-\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde D^3}^{2m}\mathcal{Z}_-^{2\lambda}}{\sqrt2}\Big)\frac{h_b\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt2}\frac{m_{u^j}\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$-\frac{8}{3}\mathcal{Z}_{\tilde D^3}^{1n}\mathcal{Z}_{\tilde D^1}^{1m}\frac{h_d\mathcal{Z}_{\tilde U^I}^{1j}\mathcal{Z}_-^{2\lambda}}{\sqrt2}\frac{h_b\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt2}\frac{m_{u^j}\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\frac{m_{u^j}\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$-\frac{8}{3}\mathcal{Z}_{\tilde D^3}^{2n}\mathcal{Z}_{\tilde D^1}^{2m}\Big(-\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde D^3}^{2m}\mathcal{Z}_-^{2\lambda}}{\sqrt2}\Big)\Big(-\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt2}\Big)$$

$$\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$+\frac{8}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde D^3}^{2n}\mathcal{Z}_{\tilde D^1}^{2m}\Big(-\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde D^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt2}\Big)\frac{m_{u^j}\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}$$

$$\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$+\frac{8}{3}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde D^3}^{2n}\mathcal{Z}_{\tilde D^1}^{2m}\Big(-\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde D^3}^{2m}\mathcal{Z}_-^{2\lambda}}{\sqrt2}\Big)\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)$$

$$\Big(F_A^{1a}+F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$+\frac{8}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{\kappa_\eta^-\mathrm{w}}}\mathcal{Z}_{\tilde D^3}^{2n}\mathcal{Z}_{\tilde D^1}^{2m}\frac{m_{u^j}\mathcal{Z}_{\tilde D^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}_{\tilde D^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big(-\mathcal{Z}_{\tilde U^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde U^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt2 m_{\mathrm{w}}\sin\beta}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}-F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde U^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde g\mathrm{w}},x_{\tilde D^3_m\mathrm{w}},x_{\tilde D^1_n\mathrm{w}})$$

$$+\frac{32}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{1n}\mathcal{Z}_{\tilde{D}^1}^{2m}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$F_A^0(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}_j^I\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}},x_{\tilde{D}_n^1\mathrm{w}})$$

$$-\frac{32}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$F_C^{1a}(x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\kappa_\lambda^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_l^I\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{32}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{1n}\mathcal{Z}_{\tilde{D}^1}^{2m}\Big(-\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde{D}^3}^{2m}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}$$

$$F_A^{1a}(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}_j^I\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}},x_{\tilde{D}_n^1\mathrm{w}})$$

$$+\frac{16}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{D}^3}^{1n}\mathcal{Z}_{\tilde{D}^1}^{2m}+\mathcal{Z}_{\tilde{D}^3}^{2n}\mathcal{Z}_{\tilde{D}^1}^{1m}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}$$

$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}_j^I\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}},x_{\tilde{D}_n^1\mathrm{w}})$$

$$+\frac{32}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{2n}\mathcal{Z}_{\tilde{D}^1}^{1m}\frac{h_d\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$F_A^{1a}(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}_j^I\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}},x_{\tilde{D}_n^1\mathrm{w}})$$

$$+\frac{32}{3}\sqrt{x_{\kappa_\lambda^-\mathrm{w}}x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{2n}\mathcal{Z}_{\tilde{D}^1}^{1m}\frac{h_d\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde{D}^3}^{2m}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$F_A^0(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}_j^I\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}},x_{\tilde{D}_n^1\mathrm{w}})$$

$$+\frac{16}{3}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{\tilde{g}\mathrm{w}}}\mathcal{Z}_{\tilde{D}^3}^{2n}\mathcal{Z}_{\tilde{D}^1}^{1m}\frac{h_d\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}_j^I\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{\tilde{g}\mathrm{w}},x_{\tilde{D}_m^3\mathrm{w}},x_{\tilde{D}_n^1\mathrm{w}})$$

$$-\frac{32}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_d\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$F_C^{1a}(x_{\tilde{U}_\alpha^i\mathrm{w}},x_{\kappa_\lambda^-\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{\tilde{U}_l^I\mathrm{w}},xmw,x_{\tilde{U}_\beta^j\mathrm{w}},x_{\tilde{g}\mathrm{w}})$$

$$+\frac{16}{3}x_{\kappa_\lambda^-\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+xmw)(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}\Big)$$

$$+\frac{16}{3}x_{\kappa_\lambda^-\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_d\mathcal{Z}_{\tilde{U}^I}^{1i}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}\Big)$$

$$+\frac{16}{3}x_{\kappa_\eta^-\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^m}^{2i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\kappa_\eta^-\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\kappa_\eta^-\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+xmw)(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}\Big)$$

$$+\frac{16}{3}x_{\kappa_\eta^-\mathrm{w}}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_d\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\kappa_\eta^-\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\kappa_\eta^-\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}\Big)$$

$$-\frac{16}{3}x_{i\mathrm{w}}^2\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^m}^{1n}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\frac{\ln x_{i\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{i\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{i\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}$$

$$-\frac{16}{3}x_{i\mathrm{w}}^2\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_d\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\frac{\ln x_{i\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{i\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{i\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}$$

$$+\frac{16}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}x_{\tilde{U}_\alpha^i\mathrm{w}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{h_d\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$\Big(\frac{\ln x_{\tilde{U}_\alpha^i\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\tilde{U}_\alpha^i\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\tilde{U}_\alpha^i\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{\tilde{U}_\alpha^i\mathrm{w}})(x_{i\mathrm{w}}-x_{\tilde{U}_\alpha^i\mathrm{w}})(-x_{\tilde{U}_i^I\mathrm{w}}+x_{\tilde{U}_l^I\mathrm{w}})}\Big)$$

$$+\frac{16}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}x_{\tilde{U}_\alpha^i\mathrm{w}}\Big(\mathcal{Z}_{\tilde{U}^i}^{2\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}+\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_{\tilde{U}^i}^{2\alpha_2}\Big)\frac{h_d\mathcal{Z}_{\tilde{U}^i}^{1\alpha_1}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha_2}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)\Big(-\mathcal{Z}_{\tilde{U}^j}^{1\beta}\mathcal{Z}_+^{1\eta}+\frac{m_{u^j}\mathcal{Z}_{\tilde{U}^j}^{2\beta}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_\mathrm{w}\sin\beta}\Big)$$

$$
\Big(\frac{\ln x_{\tilde{U}^i_\alpha \mathrm{w}}}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(-x_{\tilde{U}^i_\alpha \mathrm{w}}+x_{\tilde{U}^I_l \mathrm{w}})}
$$

$$
-\frac{x_{i\mathrm{w}}\ln x_{\tilde{U}^i_\alpha \mathrm{w}}}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(x_{i\mathrm{w}}-x_{\tilde{U}^i_\alpha \mathrm{w}})(-x_{\tilde{U}^i_\alpha \mathrm{w}}+x_{\tilde{U}^I_l \mathrm{w}})}\Big)
$$

$$
+\frac{16}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}x_{\tilde{U}^I_l \mathrm{w}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_b\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\frac{h_d\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}
$$

$$
\Big(-\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\lambda}_+ +\frac{m_{u^i}\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_+}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)\Big(-\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{1\lambda}_+ +\frac{m_{u^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_+}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)
$$

$$
\Big(\frac{\ln x_{\tilde{U}^I_l \mathrm{w}}}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})}
$$

$$
-\frac{x_{i\mathrm{w}}\ln x_{\tilde{U}^I_l \mathrm{w}}}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{i\mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})}\Big)
$$

$$
+\frac{16}{3}\sqrt{x_{\tilde{g}\mathrm{w}}x_{i\mathrm{w}}}x_{\tilde{U}^I_l \mathrm{w}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_d\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}
$$

$$
\Big(-\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{1\eta}_+ +\frac{m_{u^j}\mathcal{Z}^{2\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_+}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)\Big(-\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{1\eta}_+ +\frac{m_{u^j}\mathcal{Z}^{2\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_+}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)
$$

$$
\Big(\frac{\ln x_{\tilde{U}^I_l \mathrm{w}}}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})}
$$

$$
-\frac{x_{i\mathrm{w}}\ln x_{\tilde{U}^I_l \mathrm{w}}}{(x_{\kappa^-_\lambda \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\kappa^-_\eta \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{i\mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})(x_{\tilde{U}^i_\alpha \mathrm{w}}-x_{\tilde{U}^I_l \mathrm{w}})}\Big)+(i\leftrightarrow j)\;, \tag{119}
$$

$$
\phi^{p\tilde{g}}_3=-2\phi^{p\tilde{g}}_2\;, \tag{120}
$$

$$
\phi^{p\tilde{g}}_4=-\frac{16}{3}\sqrt{x_{\kappa^-_\lambda \mathrm{w}}x_{g\mathrm{w}}}\mathcal{Z}^{1n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\Big(-\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{1\lambda}_- +\frac{h_b\mathcal{Z}^{2m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\Big)
$$

$$
\Big(-\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{1\eta}_- +\frac{h_d\mathcal{Z}^{2n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\Big)\Big(-\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{1\eta}_+ +\frac{m_{u^j}\mathcal{Z}^{2\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_+}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)
$$

$$
\Big(F^{1a}_A-F^{1b}_A+F^{1c}_A\Big)(x_{\kappa^-_\lambda \mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma \mathrm{w}},x_{\tilde{D}^1_\delta \mathrm{w}})
$$

$$
-\frac{32}{3}\sqrt{x_{g\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}^{1n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\Big(-\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{1\eta}_- +\frac{h_d\mathcal{Z}^{2n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\Big)
$$

$$
\frac{m_{u^j}\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_+}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big(-\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{1\eta}_+ +\frac{m_{u^j}\mathcal{Z}^{2\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_+}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)
$$

$$
F^{1a}_A(x_{\kappa^-_\lambda \mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma \mathrm{w}},x_{\tilde{D}^1_\delta \mathrm{w}})
$$

$$-\frac{32}{3}\sqrt{x_{\kappa^-_\lambda \mathrm{w}}x_{\kappa^-_\eta \mathrm{w}}x_{g\mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}^{1n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\Big(-\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{1\lambda}_{-}+\frac{h_b\mathcal{Z}^{2m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\Big)$$

$$\frac{m_{u^j}\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big(-\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{1\eta}_{+}+\frac{m_{u^j}\mathcal{Z}^{2\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big)$$

$$F^0_A(x_{\kappa^-_\lambda \mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma \mathrm{w}},x_{\tilde{D}^1_\delta \mathrm{w}})$$

$$-\frac{16}{3}\sqrt{x_{\kappa^-_\eta \mathrm{w}}x_{g\mathrm{w}}}\mathcal{Z}^{1n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\frac{m_{u^j}\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}$$

$$\frac{m_{u^j}\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big(-\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{1\eta}_{+}+\frac{m_{u^j}\mathcal{Z}^{2\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}$$

$$\Big(F^{1a}_A-F^{1b}_A+F^{1c}_A\Big)(x_{\kappa^-_\lambda \mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma \mathrm{w}},x_{\tilde{D}^1_\delta \mathrm{w}})+(i\leftrightarrow j)\;, \tag{121}$$

$$\phi^{p\tilde{g}}_5=\frac{1}{4}\phi^{p\tilde{g}}_4\;, \tag{122}$$

$$\phi^{p\tilde{g}}_6=\frac{16}{3}\sqrt{x_{\kappa^-_\lambda \mathrm{w}}x_{\kappa^-_\eta \mathrm{w}}}\mathcal{Z}^{2n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\Big(-\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{1\lambda}_{-}+\frac{h_b\mathcal{Z}^{2m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\Big)$$

$$\frac{h_b\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}\Big(-\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{1\eta}_{-}+\frac{h_d\mathcal{Z}^{2n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}\Big)$$

$$\Big(F^{1a}_A-F^{1b}_A-F^{1c}_A\Big)(x_{\kappa^-_\lambda \mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma \mathrm{w}},x_{\tilde{D}^1_\delta \mathrm{w}})$$

$$-\frac{64}{3}\sqrt{x_{g\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_d\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}\frac{h_d\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}$$

$$F^{1a}_C(x_{\tilde{U}^i_{\alpha_2}\mathrm{w}},x_{\kappa^-_\lambda \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{\tilde{U}^i_{\alpha_1}\mathrm{w}},x_{i\mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{g\mathrm{w}})$$

$$+\frac{16}{3}\sqrt{x_{\kappa^-_\eta \mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}^{2n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}$$

$$\Big(-\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{1\eta}_{-}+\frac{h_d\mathcal{Z}^{2n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}\Big)\frac{m_{u^j}\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}$$

$$\Big(F^{1a}_A+F^{1b}_A-F^{1c}_A\Big)(x_{\kappa^-_\lambda \mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma \mathrm{w}},x_{\tilde{D}^1_\delta \mathrm{w}})$$

$$+\frac{16}{3}\sqrt{x_{\kappa^-_\lambda \mathrm{w}}x_{j\mathrm{w}}}\mathcal{Z}^{2n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\Big(-\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{1\lambda}_{-}+\frac{h_b\mathcal{Z}^{2m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\Big)$$

$$\frac{h_b\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}\frac{m_{u^j}\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\Big(F^{1a}_A+F^{1b}_A$$

$$-F^{1c}_A\Big)(x_{\kappa^-_\lambda \mathrm{w}},x_{\tilde{U}^i_\alpha \mathrm{w}},x_{\kappa^-_\eta \mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma \mathrm{w}},x_{\tilde{D}^1_\delta \mathrm{w}})$$

$$-\frac{16}{3}\mathcal{Z}^{2n}_{\tilde{D}^3}\mathcal{Z}^{2m}_{\tilde{D}^1}\frac{h_d\mathcal{Z}^{1j}_{\tilde{U}^I}\mathcal{Z}^{2\lambda}_{-}}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_{-}}{\sqrt{2}}\frac{m_{u^j}\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}\frac{m_{u^j}\mathcal{Z}^{1n}_{\tilde{D}^1}\mathcal{Z}^{2\eta}_{+}}{\sqrt{2}m_{\mathrm{w}}\sin\beta}$$

$$\Big(F_A^{2b}+F_A^{2c}-F_A^{2d}-F_A^{2e}-2F_A^{2f}\Big)x_{\kappa_\lambda^-\mathrm{w}},x_{\tilde{U}^i_\alpha\mathrm{w}},x_{\kappa_\eta^-\mathrm{w}},x_{j\mathrm{w}},x_{g\mathrm{w}},x_{\tilde{D}^3_\gamma\mathrm{w}},x_{\tilde{D}^1_\delta\mathrm{w}})$$

$$-32x_{\kappa_\lambda^-\mathrm{w}}\sqrt{x_{g\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_d\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\frac{h_d\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}$$

$$\Big(\frac{\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\kappa_\lambda^-\mathrm{w}}}{(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(-x_{\kappa_\lambda^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}\Big)$$

$$-32x_{\kappa_\eta^-\mathrm{w}}\sqrt{x_{g\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_d\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\frac{h_d\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}$$

$$\Big(\frac{\ln x_{\kappa_\eta^-\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\kappa_\eta^-\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\kappa_\eta^-\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{i\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(-x_{\kappa_\eta^-\mathrm{w}}+x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}\Big)$$

$$+32x_{i\mathrm{w}}^2\sqrt{x_{g\mathrm{w}}x_{i\mathrm{w}}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_d\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\frac{h_d\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}$$

$$\frac{\ln x_{i\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{i\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{i\mathrm{w}})(-x_{i\mathrm{w}}+x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(-x_{i\mathrm{w}}+x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}$$

$$-32\sqrt{x_{g\mathrm{w}}x_{i\mathrm{w}}}x_{\tilde{U}^i_{\alpha_2}\mathrm{w}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_d\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\frac{h_d\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}$$

$$\Big(\frac{\ln x_{\tilde{U}^i_{\alpha_2}\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(-x_{\tilde{U}^i_{\alpha_2}\mathrm{w}}+x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\tilde{U}^i_{\alpha_2}\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(x_{i\mathrm{w}}-x_{\tilde{U}^i_{\alpha_2}\mathrm{w}})(-x_{\tilde{U}^i_{\alpha_2}\mathrm{w}}+x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}\Big)$$

$$-32\sqrt{x_{g\mathrm{w}}x_{i\mathrm{w}}}x_{\tilde{U}^i_{\alpha_1}\mathrm{w}}\Big(\mathcal{Z}^{2\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}+\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\alpha_2}_{\tilde{U}^i}\Big)\frac{h_d\mathcal{Z}^{1\alpha_1}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\alpha_2}_{\tilde{U}^i}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\frac{h_b\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}\frac{h_d\mathcal{Z}^{1\beta}_{\tilde{U}^j}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}$$

$$\Big(\frac{\ln x_{\tilde{U}^i_{\alpha_1}\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})(x_{\tilde{U}^i_{\alpha_2}\mathrm{w}}-x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}$$

$$-\frac{x_{i\mathrm{w}}\ln x_{\tilde{U}^i_{\alpha_1}\mathrm{w}}}{(x_{\kappa_\lambda^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})(x_{\kappa_\eta^-\mathrm{w}}-x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})(x_{i\mathrm{w}}-x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})(x_{\tilde{U}^i_{\alpha_2}\mathrm{w}}-x_{\tilde{U}^i_{\alpha_1}\mathrm{w}})}\Big)+(i\leftrightarrow j)\;, \tag{123}$$

$$\phi_7^{p\tilde{g}}=-\frac{16}{3}\sqrt{x_{\kappa_\eta^-\mathrm{w}}x_{g\mathrm{w}}}\mathcal{Z}^{2n}_{\tilde{D}^3}\mathcal{Z}^{1m}_{\tilde{D}^1}\Big(-\mathcal{Z}^{1m}_{\tilde{D}^3}\mathcal{Z}^{1\lambda}_-+\frac{h_b\mathcal{Z}^{2m}_{\tilde{D}^3}\mathcal{Z}^{2\lambda}_-}{\sqrt{2}}\Big)\frac{h_b\mathcal{Z}^{1\alpha}_{\tilde{U}^i}\mathcal{Z}^{2\eta}_-}{\sqrt{2}}$$

$$
\begin{aligned}
&\Big(-\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\\
&\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{\kappa_\lambda^-{\rm w}},x_{\tilde{U}_\alpha^i{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{j{\rm w}},x_{g{\rm w}},x_{\tilde{D}_m^1{\rm w}},x_{\tilde{D}_\delta^1{\rm w}})\\
&-\frac{32}{3}\sqrt{x_{\kappa_\lambda^-{\rm w}}x_{\kappa_\eta^-{\rm w}}x_{g{\rm w}}x_{j{\rm w}}}\mathcal{Z}_{\tilde{D}^3}^{2n}\mathcal{Z}_{\tilde{D}^1}^{1m}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big(-\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_-^{1\eta}+\frac{h_d\mathcal{Z}_{\tilde{D}^1}^{2n}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\Big)\\
&\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\\
&F_A^0(x_{\kappa_\lambda^-{\rm w}},x_{\tilde{U}_\alpha^i{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{j{\rm w}},x_{g{\rm w}},x_{\tilde{D}_\gamma^3{\rm w}},x_{\tilde{D}_\delta^1{\rm w}})\\
&-\frac{32}{3}\sqrt{x_{g{\rm w}}x_{j{\rm w}}}\mathcal{Z}_{\tilde{D}^3}^{2n}\mathcal{Z}_{\tilde{D}^1}^{1m}\Big(-\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_-^{1\lambda}+\frac{h_b\mathcal{Z}_{\tilde{D}^3}^{2m}\mathcal{Z}_-^{2\lambda}}{\sqrt{2}}\Big)\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\\
&\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda}+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\\
&F_A^{1a}(x_{\kappa_\lambda^-{\rm w}},x_{\tilde{U}_\alpha^i{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{j{\rm w}},x_{g{\rm w}},x_{\tilde{D}_\gamma^3{\rm w}},x_{\tilde{D}_\delta^1{\rm w}})\\
&-\frac{16}{3}\sqrt{x_{\kappa_\lambda^-{\rm w}}x_{g{\rm w}}}\mathcal{Z}_{\tilde{D}^3}^{2n}\mathcal{Z}_{\tilde{D}^1}^{1m}\frac{h_b\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_-^{2\eta}}{\sqrt{2}}\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^3}^{1m}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\\
&\Big(-\mathcal{Z}_{\tilde{U}^i}^{1\alpha}\mathcal{Z}_+^{1\lambda})+\frac{m_{u^i}\mathcal{Z}_{\tilde{U}^i}^{2\alpha}\mathcal{Z}_+^{2\lambda}}{\sqrt{2}m_{\rm w}\sin\beta}\Big)\frac{m_{u^j}\mathcal{Z}_{\tilde{D}^1}^{1n}\mathcal{Z}_+^{2\eta}}{\sqrt{2}m_{\rm w}\sin\beta}\\
&\Big(F_A^{1a}-F_A^{1b}+F_A^{1c}\Big)(x_{\kappa_\lambda^-{\rm w}},x_{\tilde{U}_\alpha^i{\rm w}},x_{\kappa_\eta^-{\rm w}},x_{j{\rm w}},x_{g{\rm w}},x_{\tilde{D}_\gamma^3{\rm w}},x_{\tilde{D}_\delta^1{\rm w}})+(i\leftrightarrow j)\;, \qquad (124)
\end{aligned}
$$

$$
\phi_8^{p\tilde{g}}=\frac{1}{4}\phi_7^{p\tilde{g}}\;. \qquad (125)
$$

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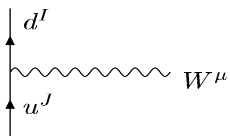
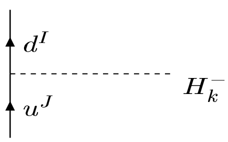
(a)



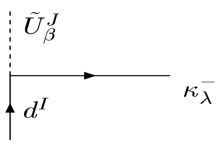
$$-\frac{ie}{\sqrt{2}sin\theta_w}\gamma^\mu\omega_- C^{IJ}$$

(b)



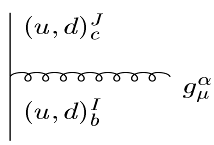
$$\frac{ie}{\sqrt{2}sin\theta_w}(h^{d^i}Z_H^{1k}\omega_- + \frac{m_{u^j}}{m_\omega sin\beta}Z_H^{2k}\omega_+)C^{IJ}$$

(c)



$$\frac{ie}{sin\theta}((-Z_{\tilde{U}^I}^{1\beta*}Z_+^{1\lambda} + \frac{m_{u_s}}{\sqrt{2}m_w sin\beta}Z_{\tilde{U}^i}^{2\beta*})\omega_- + h^{d^I}Z_{\tilde{U}^I}^{1\beta*}Z_+^{2\lambda*}\omega_+)$$

(d)

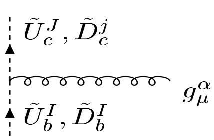


$$-ig_sT_{bc}^a\gamma_\mu\delta^{IJ}$$

k

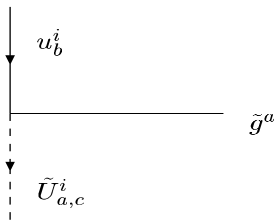
(e)

P

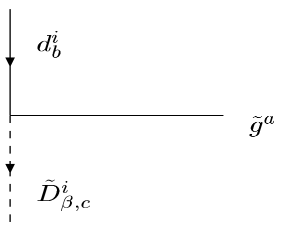


$$-ig_sT_{bc}^a(P+k)_\mu\delta^{IJ}$$

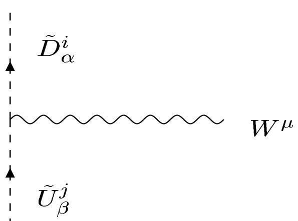
Figure 1: The Feynman-rules which are adopted in the calculations (Part I).

(a) 

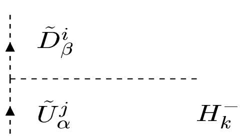
$$ig_s\sqrt{2}T^a_{bc}(-Z^{1\alpha*}_{\tilde{U}^i}\omega_- + Z^{2\alpha*}_{\tilde{U}^i}\omega_+)$$

(b) 

$$ig_s\sqrt{2}T^a_{bc}(-Z^{1\beta}_{\tilde{D}^i}\omega_- + Z^{2\beta}_{\tilde{D}^i}\omega_+)$$

(c) 

$$-\frac{ie}{\sqrt{2}\sin\theta_w}Z^{1\alpha}_{\tilde{D}^i}Z^{1\beta}_{\tilde{U}^j}C^{ij}(P+k)^\mu$$

(d) 

$$iC^{ij}(\frac{1}{\sqrt{2}}(-\frac{e^2}{2sin^2\theta_w}\upsilon_l Z^{lk}_H + 2h^2_{d^3}\upsilon_l Z^{lk}_H + \frac{2m^2_{u^i}}{\upsilon_2}Z^{2k}_H)Z^{1\beta*}_{\tilde{D}^j}Z^{1\alpha*}_{\tilde{U}^i})$$
$$-\frac{2\sqrt{2}m_\omega sin\theta_w}{e}\delta^{1k}\frac{m_{u^i}m_{d^j}}{v_1 v_2}Z^{2\beta*}_{\tilde{D}^j}Z^{2\alpha*}_{\tilde{U}^i} + Z^{1k}_H\mu^*\frac{\sqrt{2}m_{u^i}}{v_2}Z^{2\alpha*}_{\tilde{U}^i}Z^{1\beta*}_{\tilde{D}^j}$$
$$-Z^{2k}_H\mu\sqrt{2}h_{d^j}Z^{1\alpha*}_{\tilde{U}^i}Z^{2\beta*}_{\tilde{D}^j})$$

Figure 2: The Feynman-rules which are adopted in the calculations (Part II).

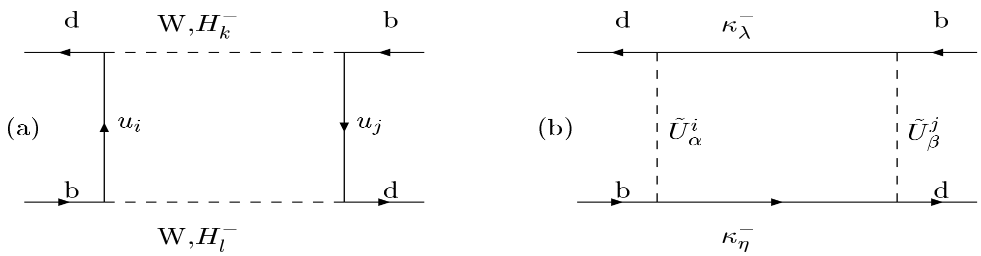


Figure 3: The box-diagrams contributing to the $B^0 - \overline{B}^0$ mixing in the supersymmetric model with minimial flavor violation. In the calculations, the crossed diagrams should be included.

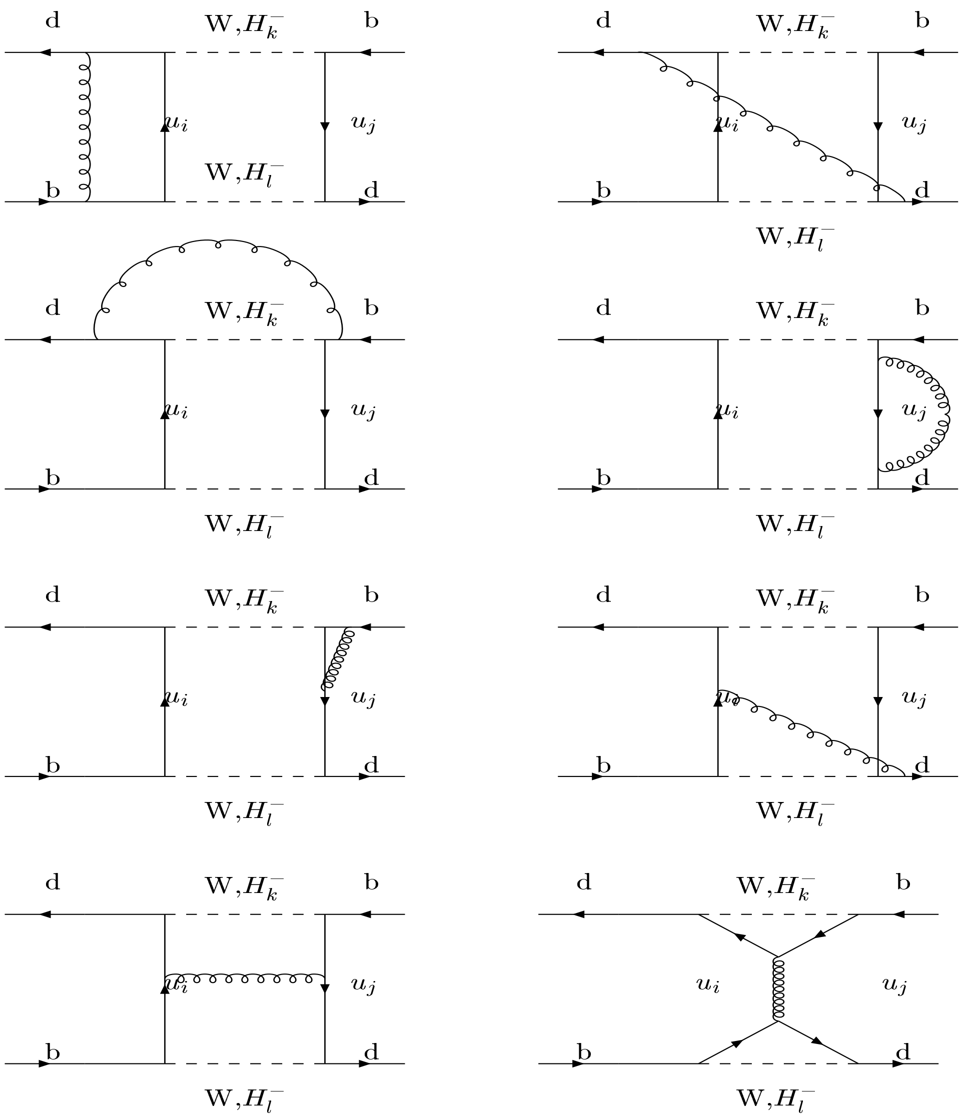


Figure 4: The diagrams responsible for QCD-corrections in the framework of the SM and THDM. In the calculations, the crossed diagrams should be included.

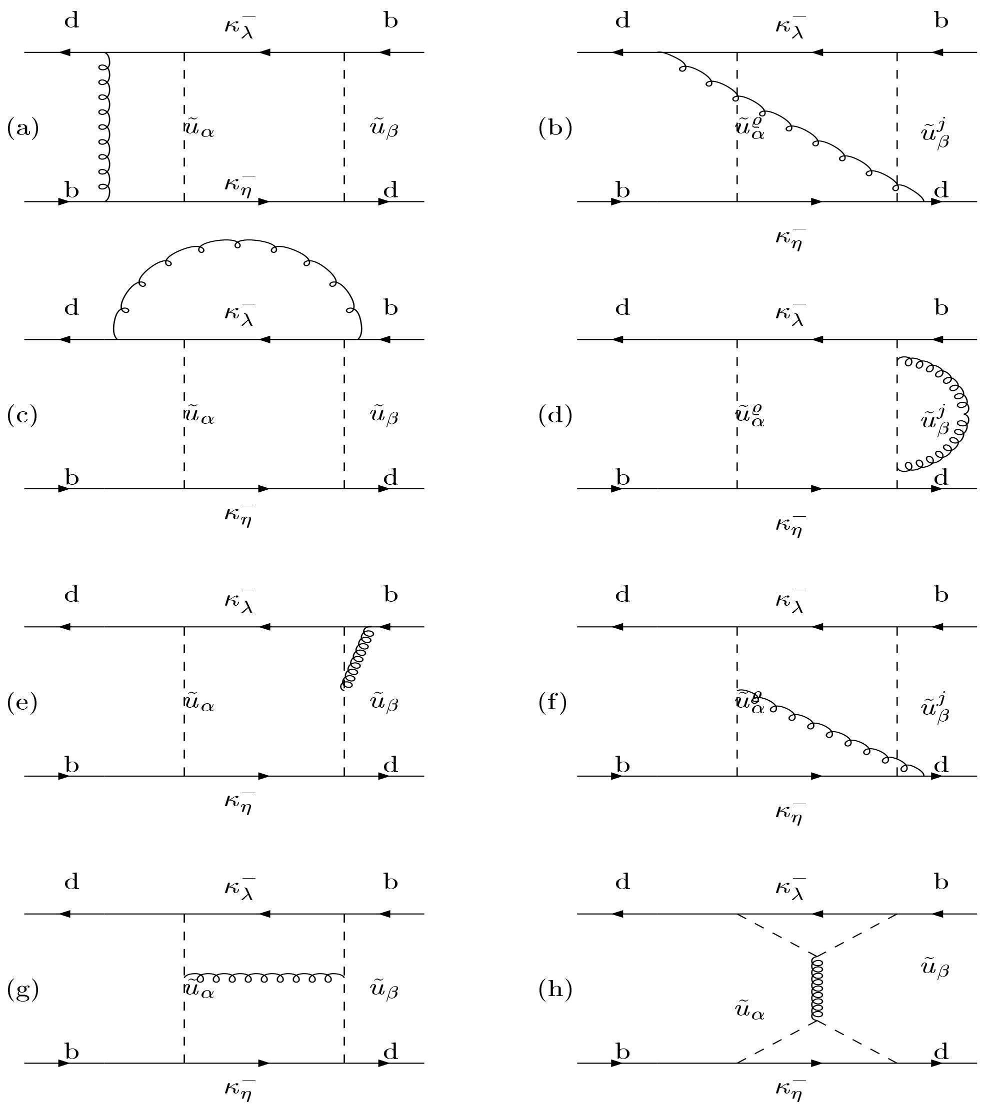


Figure 5: The diagrams responsible for QCD-corrections caused by the gluon sector of the supersymmetric model with minimial flavor violation. In the calculations, the crossed diagrams should be included.

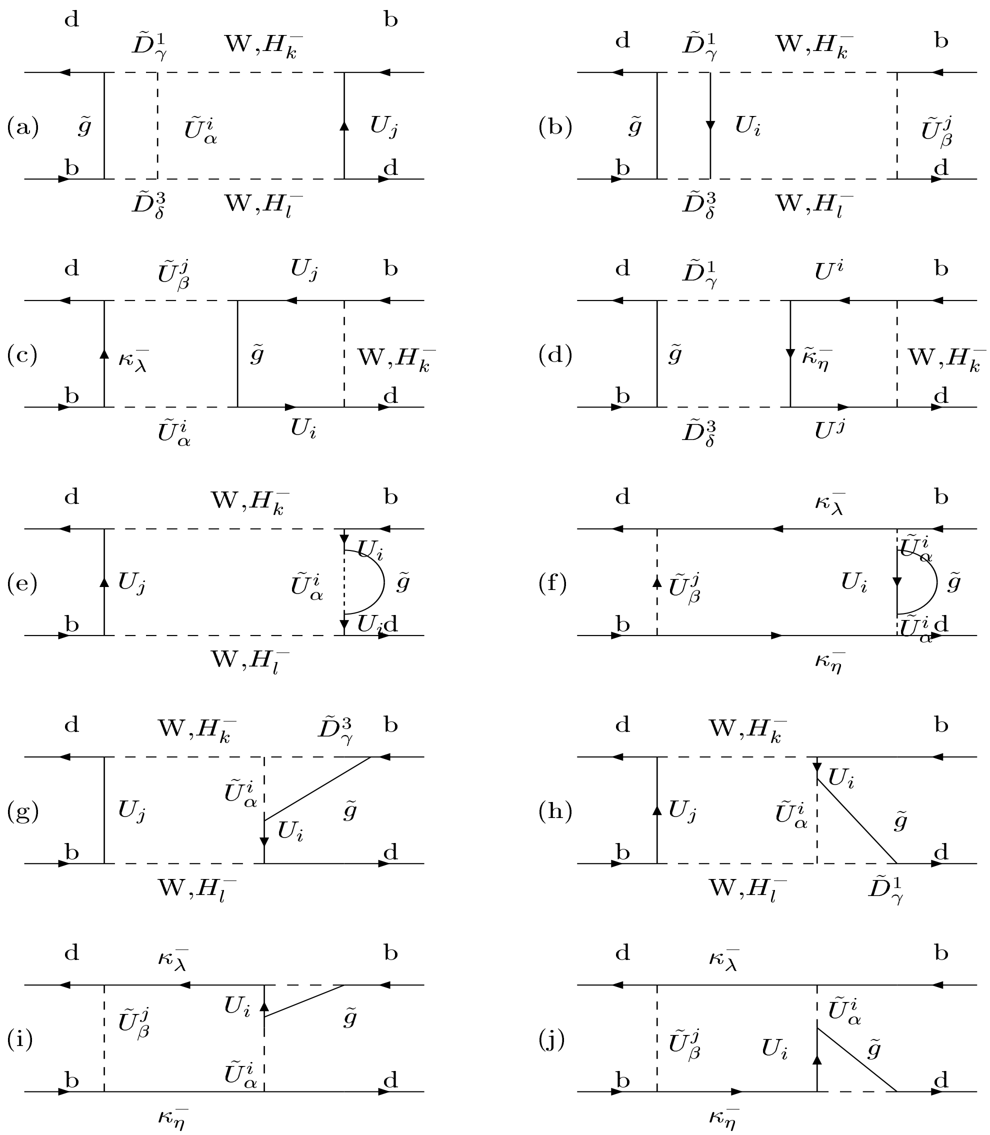
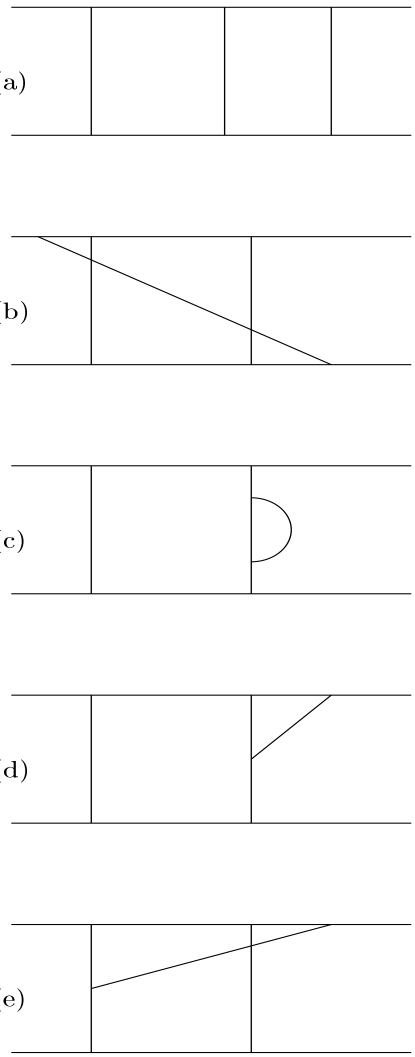


Figure 6: The diagrams responsible for QCD-corrections caused by the gluino sector of the supersymmetric theory with minimial flavor violation. In the calculations, the crossed diagrams should be included.



(a)

(b)

(c)

(d)

(e)

Figure 7: The five topological classes of diagrams appearing in the NLO-corrections to $B^0 - \overline{B}^0$.

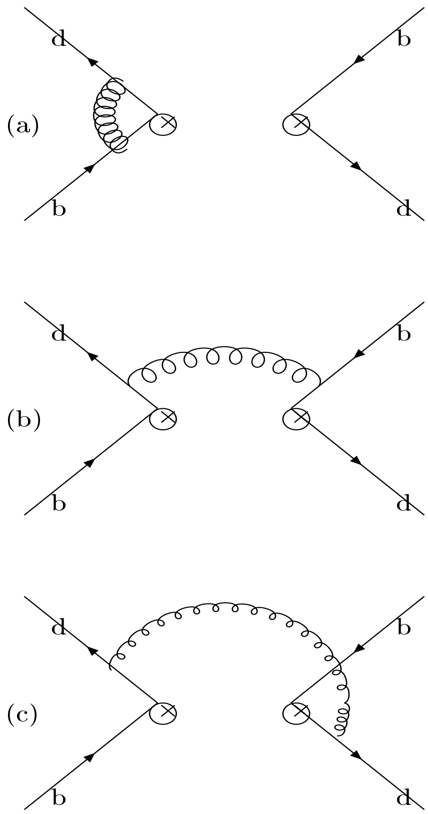


Figure 8: Classes of diagrams in the effective theory contributing to Q_i up to order α_s.

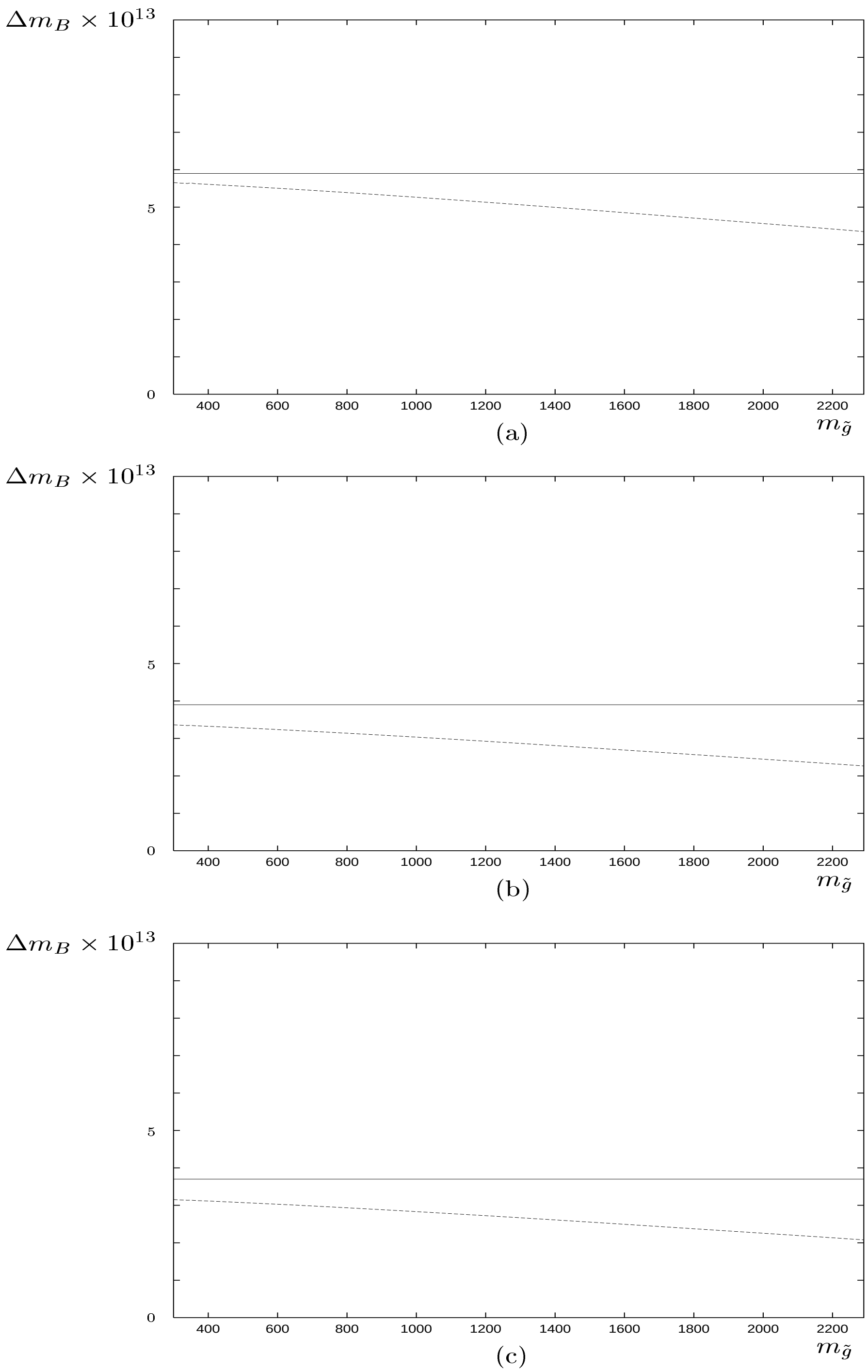


Figure 9: The Δm_B versus the gluino mass with $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{B}} = \tan\zeta_{\tilde{D}} = 0.$ and (a)$\tan\beta = 1$, (b)$\tan\beta = 5$, (c)$\tan\beta = 30$. The dot-line corresponds to the results including the gluino-corrections and solid-line corresponds to that without the gluino-corrections. The other parameters are taken as in the text.

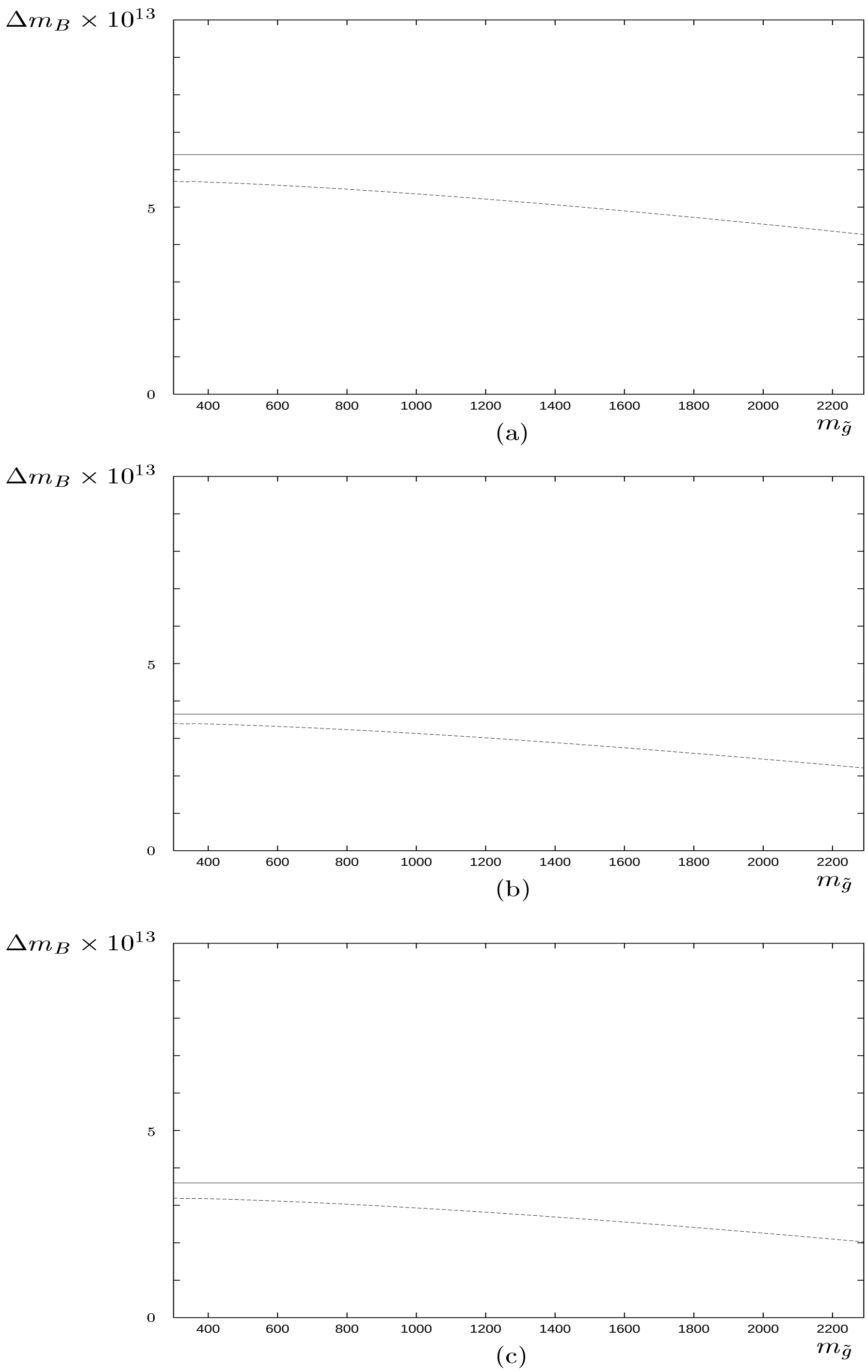


Figure 10: The Δm_B versus the gluino mass with $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{B}} = \tan\zeta_{\tilde{D}} = 0.1$. and (a)$\tan\beta = 1$, (b)$\tan\beta = 5$, (c)$\tan\beta = 30$. The dot-line corresponds to the results including the gluino-corrections and solid-line corresponds to that without the gluino-corrections. The other parameters are taken as in the text.

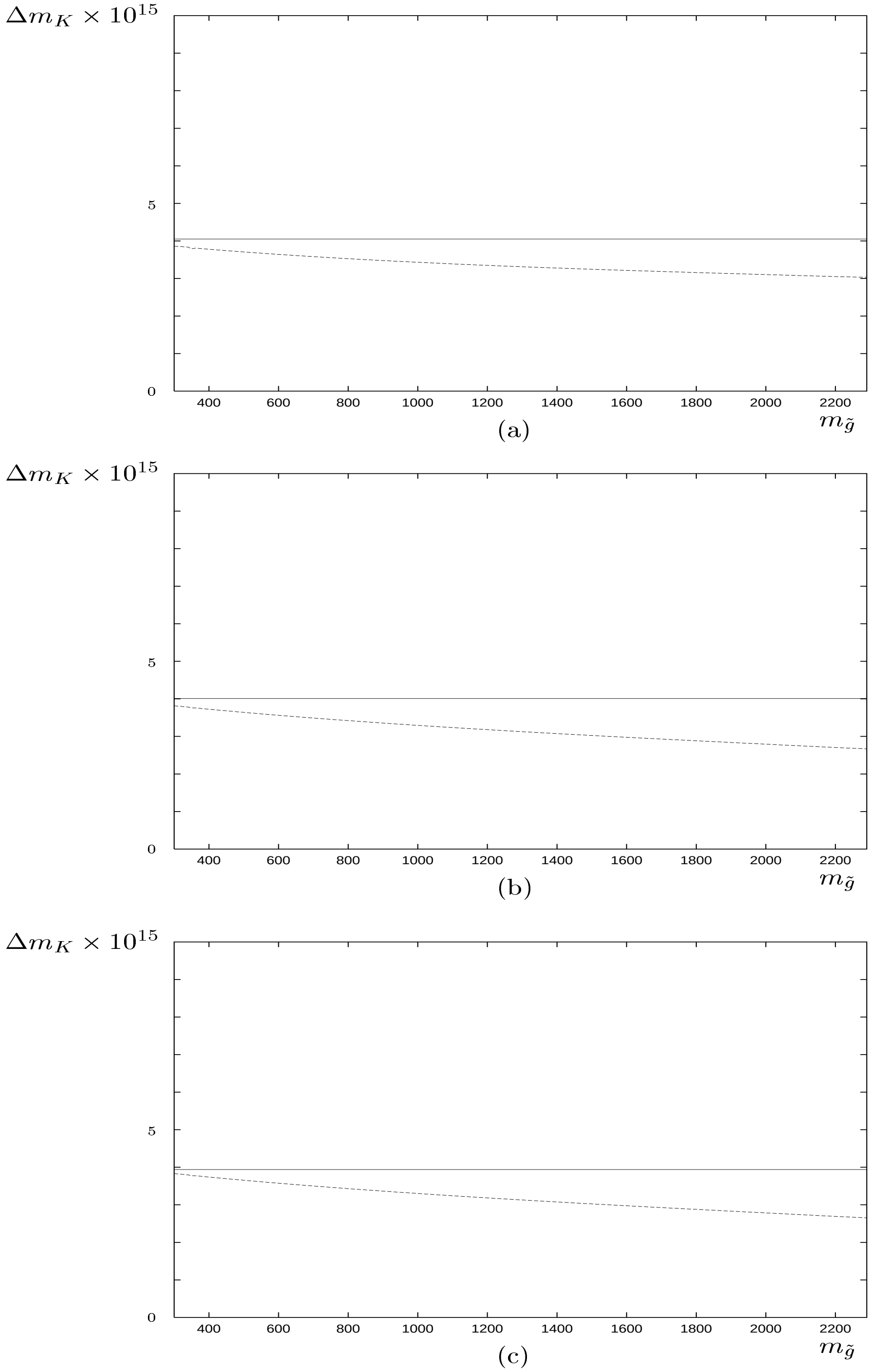


Figure 11: The Δm_K versus the gluino mass with (a) $\tan\beta = 1.5$, (b)$\tan\beta = 5$, (c)$\tan\beta = 30$, where $\tan\xi_{\tilde{U}^I} = \tan\zeta_{\tilde{B}} = \tan\zeta_{\tilde{D}} = 0$. The dot-line corresponds to the results including the gluino-corrections and solid-line corresponds to that without the gluino-corrections. The other parameters are taken as in the text.